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PROPELLING CHARGE CONTAINER LEAK RATE

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AUGUST 1979

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A theoretical method was developed for predicting the rate of gas leakage into, or out of, standard propelling charge shipping containers as a function of the experienced pressure differential as a means to establish reasonable quality assurance acceptance criteria for the shipping containers. Theoretical results were verified by laboratory testing, and curves relating leak rate to effective hole diameter were constructed. A series of tests were performed on loaded containers to establish acceptable leakage rates/hole sizes and to determine

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the minimum transducer sensitivity needed for implementation on automated load and pack (LAP) lines.

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FOREWORD

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INTRODUCTION

The performance of any smokeless propellant used in cannon artillery depends to a great extent upon the total moisture content of the propellant grains. Since all smokeless propellants are hygroscopic to some degree, various packaging methods have been adopted in order to allow the user to hold to the old maxim of "keeping the powder dry." The accepted practice for the bagged propellant used in separate loading ammunition has been to transport and store the propellant until needed in reusable, sealed metal containers.

The propellant containers presently utilized are tested for any leaks that could possibly admit moisture immediately after fabrication, and again immediately after being loaded. However, there does not exist a definite testing specification for the leak test after loading and the specification for the leak test after manufacture is worded broadly and is non-specific in regard to any leakage rate or equivalent leakage hole size. As a result, the present testing methods are capable of detecting only gross leakage and do not provide an adequate measure of the containers' ability to exclude moisture from reaching the propellant.

To rectify this situation, a study was conducted to:

1. Establish the relationship between leak rate and equivalent hole size for the various containers.

2. Measure the actual leakage rate on a large sample size of each container used to establish the upper limit of the leakage rate for inclusion in a realistic testing specification.

3. Determine the availability and identify manufacturers of leak rate detection equipment that is applicable for use on automated LAP lines.

This report documents the efforts and results of these tasks.

THEORETICAL LEAK RATE PREDICTION

Previous theoretical and experimental work has been done in the field of relating geometric configuration to flow and pressure differences. One facet of this work, based on the findings of HALL[1], was reported by Slawsky, Schmidlin, and Lutzky.[2] Their work showed that the performance of a fixed-orifice pneumatic component under given operating conditions could be predicted to within five percent accuracy by consideration of only the orifice upstream conditions and a numerical parameter defined as the flow factor.

Extensive theoretical and experimental studies have shown that

$$\left(\frac{Q}{P_u}\right)_1 = 2F\sqrt{r\,(1-r)} \tag{1}$$

and

$$\left(\frac{Q}{P_u}\right)_2 = \sqrt{\frac{4}{3}}\;F\sqrt{1-r^2} \tag{2}$$

and

$$\left(\frac{Q}{P_u}\right)_3 = \sqrt{\frac{8}{5}}\;F\sqrt{r\,(1-r)\,(3-r)} \tag{3}$$

where

- Q = Volumetric flow rate
- P_u = Absolute upstream pressure (PSIA)
- F = Flow factor
- r = The ratio of absolute downstream to absolute upstream pressure (Pd/Pu)
- 1,2,3 = Subscripts that denote the upper, lower, and average expected values respectively

If the flow rate and pressures are either known or specified, the previous equations may be solved for the expected values of the flow factor as follows:

$$F_1 = \frac{(Q/P_u)}{2\sqrt{r(1-r)}} \tag{4}$$

$$F_2 = \frac{(Q/P_u)}{\sqrt{\frac{4}{3}}\sqrt{1-r^2}} \tag{5}$$

$$F_3 = \frac{(Q/P_u)}{\sqrt{\frac{8}{3}}\sqrt{r(1-r)(3-r)}} \qquad (6)$$

The flow factor for a given set of conditions can usually be obtained by actual measurements of flow. If the leakage path in the container is considered as a short duct whose diameter is small compared to the diameters of the channels it connects, then the following expression may be used to calculate the flow factor:

$$F = 16.5A \qquad (7)$$

where A is the cross sectional area of the leakage path, in square inches.

Assuming a circular cross sectional area for the leakage path results in the equation:

$$F = 13D^2 \qquad (8)$$

where D is the diameter of the leakage path.

Using this expression in Equations 4 to 6 and solving for the diameter yields:

$$D_1^2 = \frac{(Q/P_u)}{26\sqrt{r(1-r)}} \qquad (9)$$

$$D_2^2 = \frac{(Q/P_u)}{13\sqrt{\frac{4}{3}}\sqrt{1-r^2}} \qquad (10)$$

$$D_3^2 = \frac{(Q/P_u)}{13\sqrt{\frac{8}{5}}\sqrt{r(1-r)(3-r)}} \qquad (11)$$

Equations 9, 10, and 11 illustrate that if the leakage rate is known or specified in some manner, the hole diameter representative of that leakage rate can be bounded.

Considering the perfect gas law as applied to the containers:

$$p_1V = m_1 RT \qquad P_2V = m_2 RT \qquad (12)$$

so that

$$(p_1 - p_2)\, V = (m_1 - m_2)\, RT \tag{13}$$

or

$$(m_1 - m_2) = \frac{(p_1 - p_2)V}{RT} \tag{14}$$

Since $(m_1 - m_2)$ is the mass loss in pounds mass, we must convert this to standard cubic feet by multiplying by the factor RT/p_a so that

$$(m_1 - m_2)\frac{RT}{p_a} = \frac{(p_1 - p_2)}{RT}\,\frac{RT}{p_a}\, V \tag{15}$$

or

$$(m_1 - m_2)\,\frac{RT}{p_a} = \frac{(p_1 - p_2)V}{p_a} \tag{16}$$

Since this is the volume of gas lost through the leak it is equivalent to the volumetric flow rate, Q, multiplied by the time duration, Δt, over which the pressure change $(p_1 - p_2)$ takes place. This leads to

$$Q\Delta t = (m_1 - m_2)\,\frac{RT}{p_a} = \frac{(p_1 - p_2)V}{p_a} \tag{17}$$

or

$$Q = \frac{(p_1 - p_2)V}{p_a \Delta t} = \frac{V}{p_a}\,\frac{\Delta p}{\Delta t} \tag{18}$$

where V = Volume of gas in container (cubic feet)
Δp = Pressure change
p_a = Absolute pressure (14.7 PSI)
Δt = Time interval during the pressure change (minutes)

Using the results of Equation 18 in Equations 9 to 11 and also noting that

$$P_u = P_i + p_a \tag{19}$$

where P_i is the internal pressure in the container, the equations for determining hole diameters become

$$D_1^2 = \frac{V}{p_a} \frac{\Delta p}{\Delta t} \frac{1}{(P_i+p_a)} \frac{1}{26\sqrt{r(1-r)}} \qquad (20)$$

$$D_2^2 = \frac{V}{p_a} \frac{\Delta p}{\Delta t} \frac{1}{(P_i+p_a)} \frac{1}{13\sqrt{\frac{4}{3}}\sqrt{1-r^2}} \qquad (21)$$

$$D_3^2 = \frac{V}{p_a} \frac{\Delta p}{\Delta t} \frac{1}{(P_i+p_a)} \frac{1}{13\sqrt{\frac{8}{5}}\sqrt{r(1-r)(3-r)}} \qquad (22)$$

For testing purposes it is easier to measure volume in cubic inches and time in seconds with the result that the equations become

$$D_1^2 = \frac{60}{1728} V \frac{\Delta p}{\Delta t} \frac{1}{p_a(P_i+p_a)} \frac{1}{26\sqrt{r(1-r)}} \qquad (23)$$

$$D_2^2 = \frac{60}{1728} V \frac{\Delta p}{\Delta t} \frac{1}{p_a(P_i+p_a)} \frac{1}{13\sqrt{\frac{4}{3}}\sqrt{1-r^2}} \qquad (24)$$

$$D_3^2 = \frac{60}{1728} V \frac{\Delta p}{\Delta t} \frac{1}{p_a(P_i+p_a)} \frac{1}{13\sqrt{\frac{8}{5}}\sqrt{r(1-r)(3-r)}} \qquad (25)$$

where:

V = Free volume in the container (in^3)

$\Delta p/\Delta t$ = Pressure decay rate ($lb/in^3/sec$)

p_a = Absolute pressure (14.7 lb/in^3)

P_i = Container internal pressure (lb/in^3)

r = Ratio of downstream to upstream absolute pressures (P_d/P_u , dimensionless)

LABORATORY TESTING

In order to validate the results predicted by the theory, a series of tests were conducted utilizing an empty M19A2 container. The laboratory test arrangement is shown in Figure 1.

For testing, the propellant container was half filled with water. This was done based on results of earlier testing which indicated that the average ullage volume in a loaded container was approximately 50 percent of the container's total volume. The container was connected to a pressure source by utilizing the threaded hole for the container vent plug. A valve was included in the line to the pressure source to isolate the container during the leak rate testing. A direct reading pressure gage was connected as shown to give a gross indication of container pressure and a Pace-Wianco pressure transducer driving a Hewlett-Packard model 7005B X-Y recorder was included to obtain the pressure-time decay curve. For more precise pressure determination, an Ashcroft Digigage Model BCDO-500 digital water manometer was included as shown. Leakage paths were simulated by venting the container to the atmosphere by means of a vent line employing incrementally variable orifices. A valve was included in the vent line to start and stop the leak test. The test procedure was as follows:

1 An orifice of known value was connected to the vent line, and the vent line valve was closed.

2. The pressurization valve was opened and the container was brought to a specific pressure.

3. The pressurization valve was then closed and the container pressure was allowed to stabilize.

4. At the end of the stabilization period, the pressure indicated by the water manometer was marked adjacent to the pen location on the X-Y recorder.

5. The vent line valve was then opened to allow the container to experience a simulated leak at the same time the X-Y recorder time sweep was activated to provide a graphical record of the container pressure as a function of time.

6. At the end of the test, the vent line valve was closed and the test sequence repeated for a new orifice size or a new initial container pressure.

Figure 2 presents the results of the laboratory testing for four initial container pressures and simulated leakage holes from 150 to 750 micrometers (0.006 to 0.30 inches) in diameter. The plotted curves were based upon Equation 20, and represent the upper bound on the

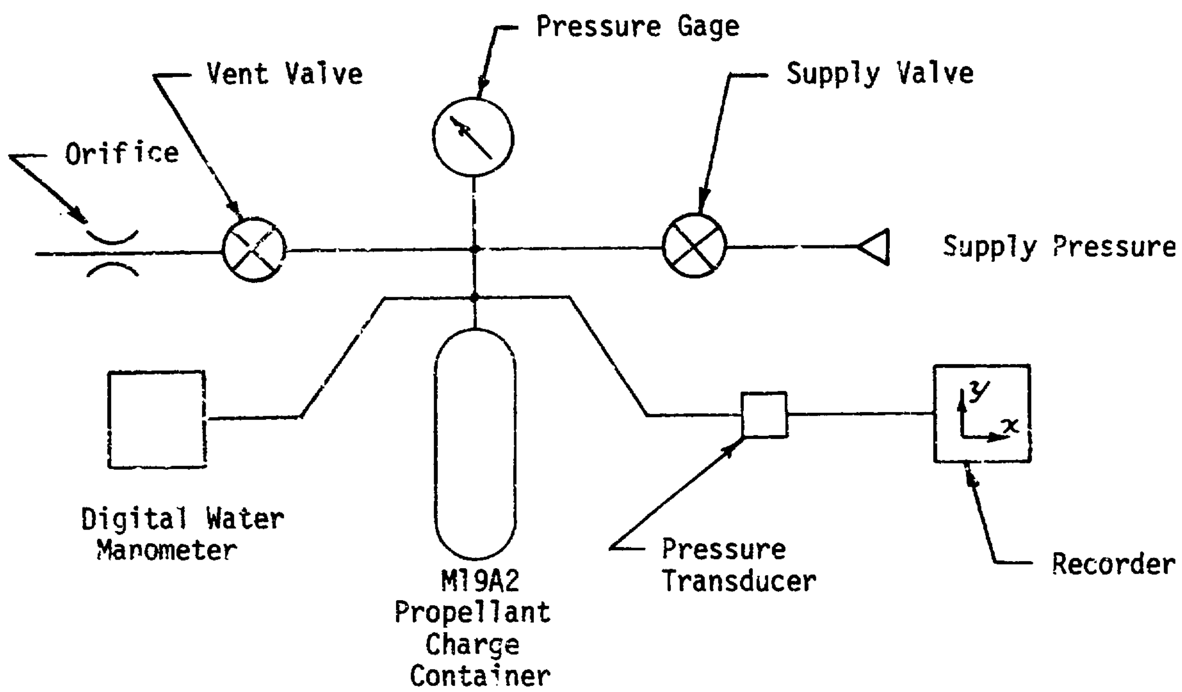

Figure 1. Laboratory Test Equipment Arrangement

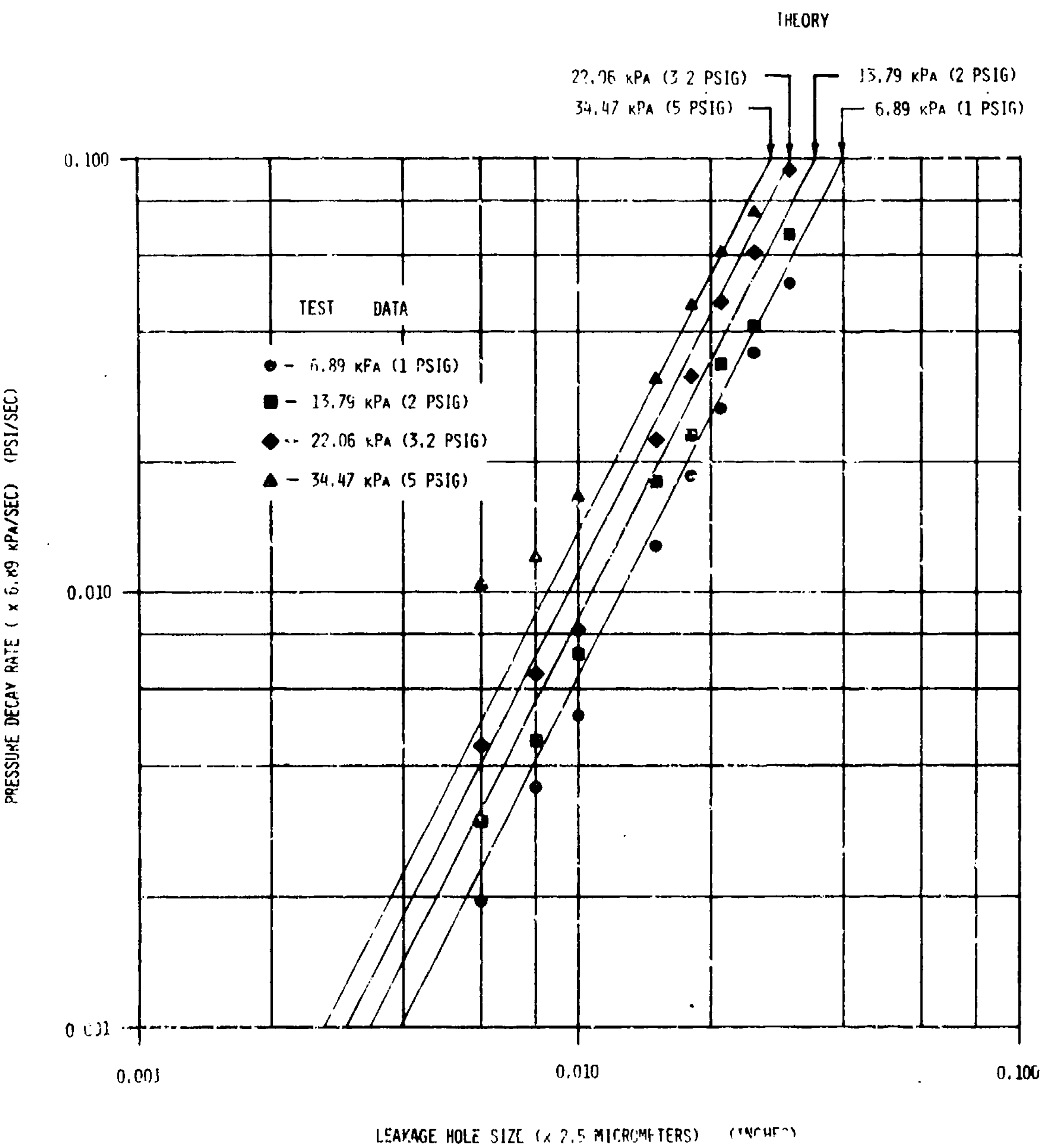

Figure 2. Laboratory Test Results for the M19A2 Container – 50% Ullage Volume

leakage rate as predicted by theory. As can be seen, there is a high degree of agreement between the test data and the values predicted by the theory with the exception of the data points representing small leakage hole sizes at the higher pressures.

This anomaly could be explained in one of two ways:

1. Leakage paths existed in the test equipment and were not apparent at the lower test pressures, or

2. Additional leakage paths were being created in the container seal at the higher pressures.

To test which of the two postulates was in fact true, the container was replaced by a stainless steel Hoke sampling cylinder which was known to exhibit no leakage. The remainder of the test equipment was unchanged.

Figure 3 presents the results of testing with the Hoke sampling cylinder utilizing an initial pressure of 34.5 kPa (5.0 PSIG) and the same family of orifices as used with the M19A2 container. The results clearly indicate that the test arrangement by itself did not introduce any unexpected leakage paths, so that the first postulated cause can be ignored.

The additional leakage paths therefore were being produced in the container lid seal and can be explained as follows: at relatively high internal pressure, the net force applied to the inner surface of the container lid is sufficient to cause the lid seal to lose part of its sealing efficiency and allow some leakage to occur around the periphery of the lid. This condition is more evident for the smaller orifice sizes because the container internal pressure remains at the relatively high pressure condition for a longer period of time. At the larger orifice sizes, the container's internal pressure drops sufficiently fast to cause the additional leakage produced by the lid to be a second order effect not readily observable during the conduct of the test.

It was therefore concluded that the developed theory was sufficiently accurate for predicting leakage hole size based on observed leakage rate provided the container test pressure did not exceed approximately 27.6 kPa (4.0 psig).

The Leakage Rate Curves

Equations 23 and 24 can be solved for the pressure/time decay rate and yield

$$\left(\frac{\Delta p}{\Delta t}\right)_1 = 748.8 \frac{1}{V_u} D^2 \, p_a \, (P_i + p_a) \sqrt{r(1-r)} \qquad (26)$$

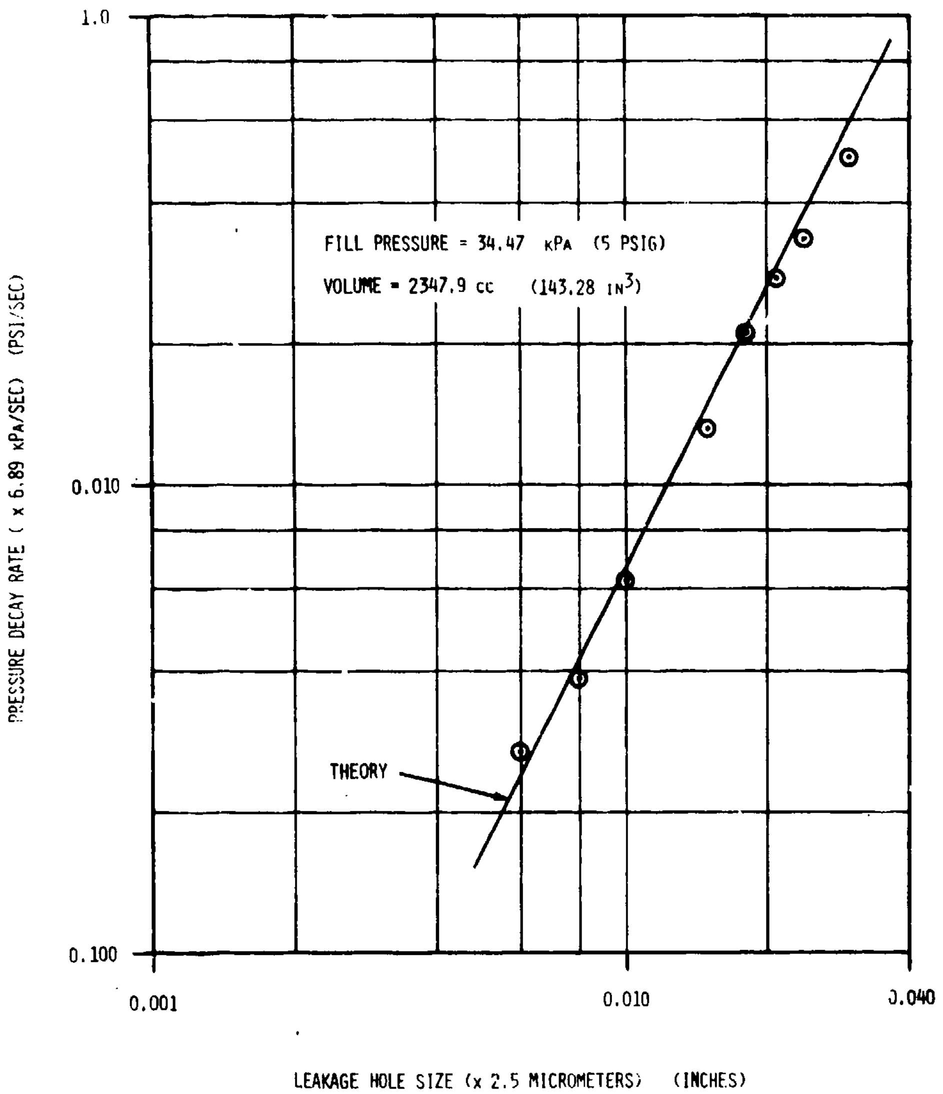

Figure 3. Laboratory Test Results for Hoke Sampling Cylinder

$$\left(\frac{\Delta p}{\Delta t}\right)_2 = 432.3 \frac{1}{V_u} D^2 p_a (P_i+p_a) \sqrt{1-r^2} \quad (27)$$

It can be seen that the pressure decay rate varies with the effective leakage hole diameter, the container's initial pressure, and the ullage volume present in the container. If we now define a new variable, α , as

$$\alpha = V_u \left(\frac{\Delta p}{\Delta t}\right), \quad (28)$$

we eliminate any variance with respect to container ullage volume and we have α as a function of only the initial container pressure and the leakage hole size, so that

$$\alpha_1 = 748.8 D^2 p_a (P_i+p_a) \sqrt{r(1-r)} \quad (29)$$

$$\alpha_2 = 432.3 D^2 p_a (P_i+p_a) \sqrt{1-r^2} \quad (30)$$

Figures 4 and 5 show the variation of the quantities α_1 and α_2 as a function of effective leakage hole size for container initial pressures between 6.9 and 34.5 kPa (1 and 5 psig).

These curves can be utilized in the following ways:

1. Given the maximum permissible leakage hole for a container, one would enter the abscissa of Figures 4 or 5 and read up to the intersection with the curves for the desired test pressure. The corresponding values of α_1 and α_2 could then be read off of the ordinate scale. Dividing these values by the container ullage volume would then yield the limits of permissible leakage rate for that container, or

2. Using the leakage rate determined from testing a container, one would multiply the leakage rate by the container's ullage volume and enter the ordinate of Figure 4 or 5 with this value. One would then read across to the intersection of this value with the two curves representing the actual container test pressure, and then read the corresponding values from the abscissa to obtain the size range of the effective leakage hole.

Ullage volume for either the loaded or unloaded container can be accurately determined by employing the method used by Goes[3].

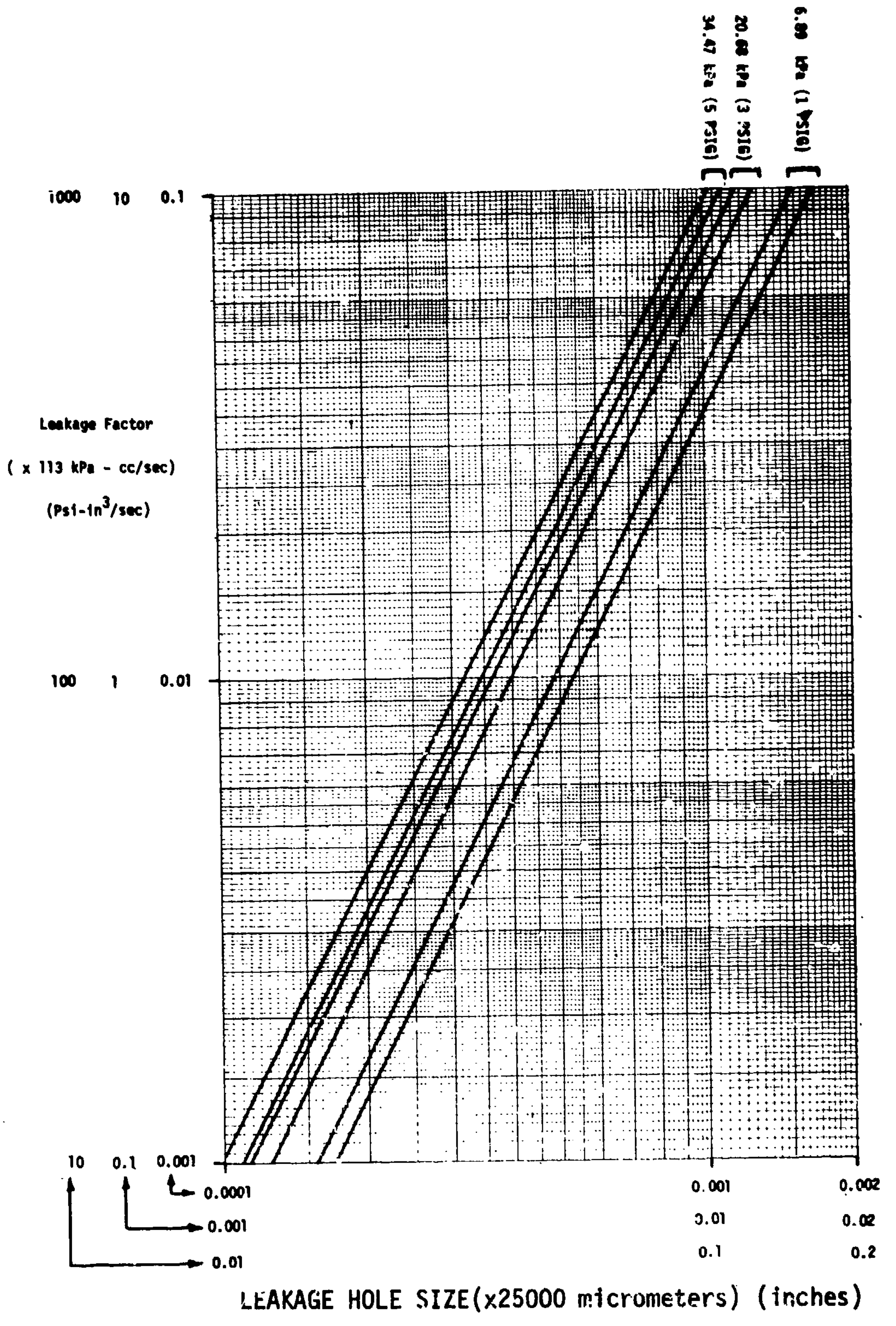

Figure 4. Leakage Factor curves for 6.89, 20.68, and 34.47 kPa (1, 3, and 5 PSIG)

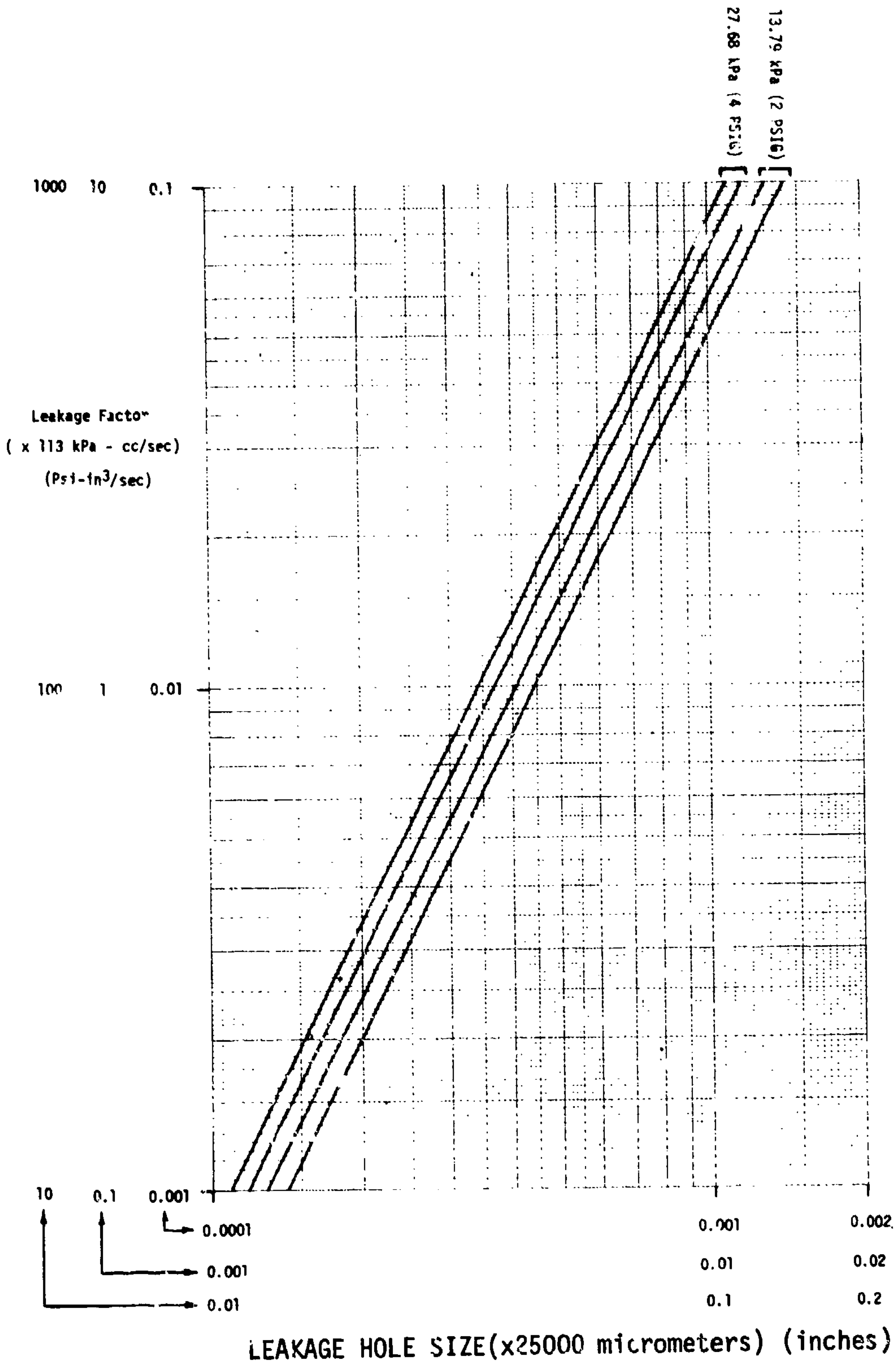

Figure 5. Leakage Factor Curves for 13.79 and 27.58 kPa (2 and 4 PSIG)

LOADED CONTAINER TESTING

Background

As a result of previous work and the current efforts on leak determination in propellant charge containers, sufficient information was available to determine leakage rates or equivalent hole sizes by the method of pressure decay per unit time.

The problem which remained was the specification of a practical leakage rate as a standard for testing propellant charge containers from a manufacturing standpoint.

It was suggested that, by measuring the leakage rates or equivalent hole sizes in standard loaded propellant charge containers which had previously been deemed acceptable at a LAP facility, a maximum acceptable leakage rate could be determined.

The container testing was comprised of three specific operations. First the ullage volume within each container was determined, next the pressure decay leak test was performed, and finally the lid torque was checked.

Testing Equipment and Test Sequence

Figure 6 illustrates the test equipment arrangement used for the ullage volume determination and leak testing. The instrumentation consisted of an Ashcroft Digital Water Manometer (0.-500 in. differential), a Himmelstein Digital Pressure Decay Leak Tester, a pneumatic control box, a reference container and the necessary pneumatic supply and control lines connecting these items together and to the container test probe shown in Figure 7. Figures 8 and 9 present in mo detail the arrangement of the control box and reference container and th functions located on the control box, respectively. The control box was used for regulating pneumatic power to the valve controls and the test probe clamping cylinder, and also for pressurizing the reference container. Pneumatic power was provided by a shop air system that was capable of delivering 551.6 kPa (80 psig) and was connected to the control box by a quick disconnect coupling. The test probe was attached to the container being tested by means of the clamp and clamping cylinder shown in Figure 7.

For clarity in following the testing sequence, Figure 10 presents the test arrangement in schematic form. The detailed test procedure was as follows:

1. Record container type, lot, and charge.
2. Turn all valves on the control box OFF.
3. Connect pneumatic power to the control box.

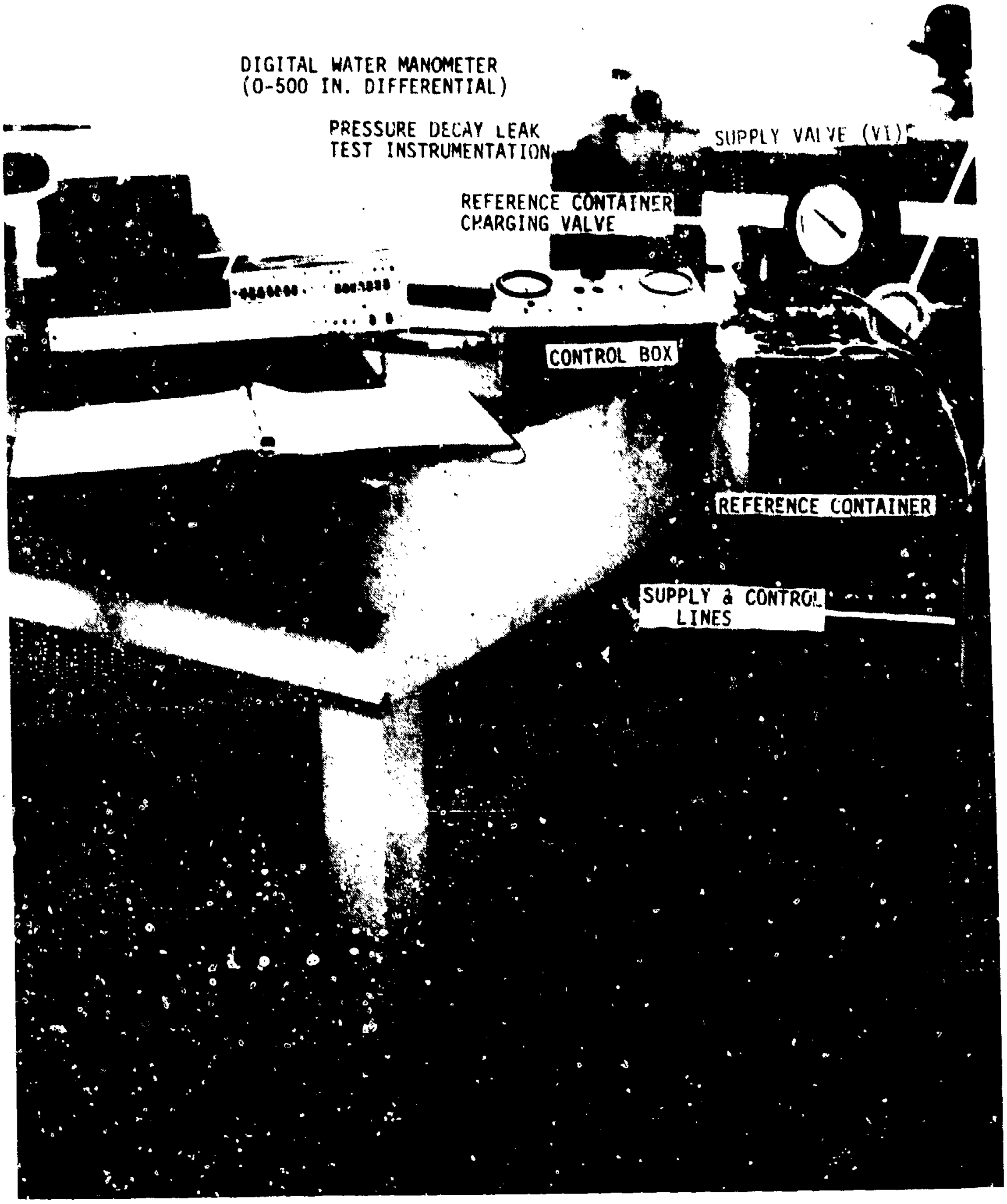

Figure 6. Test Equipment Arrangement at Aberdeen Proving Ground

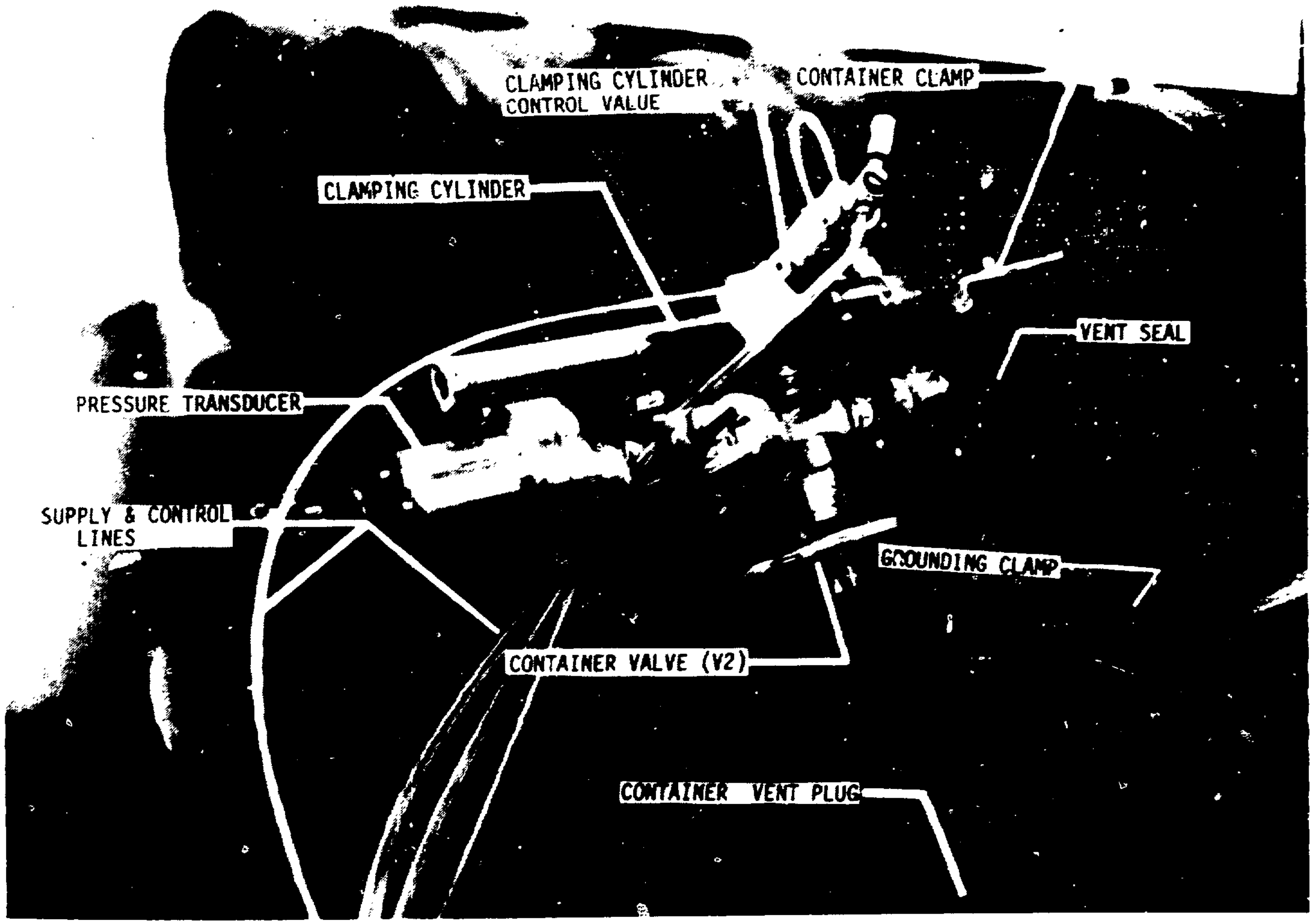

Figure 7. Container Test Probe

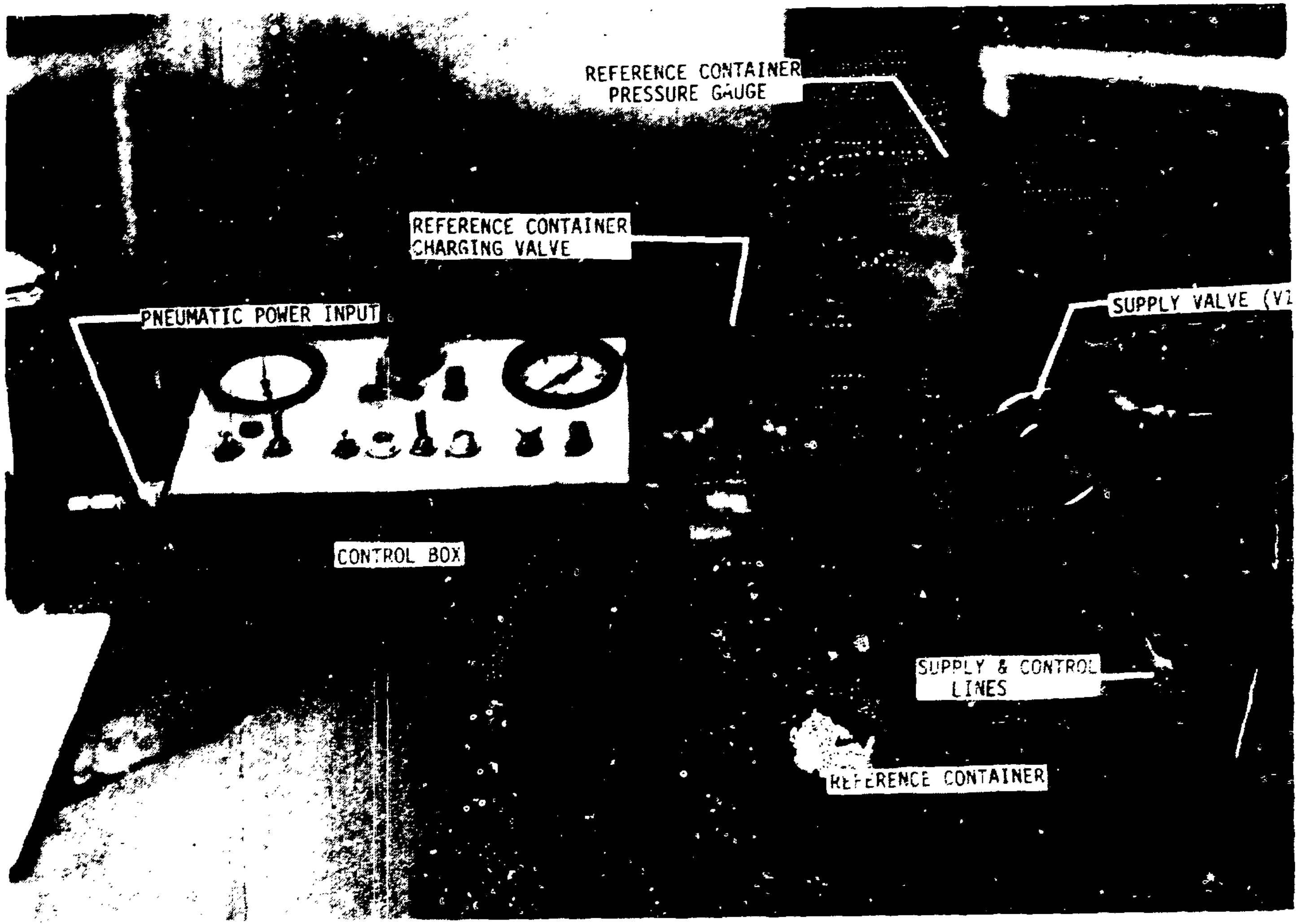

Figure 8. Detail of Control Box and Reference Container

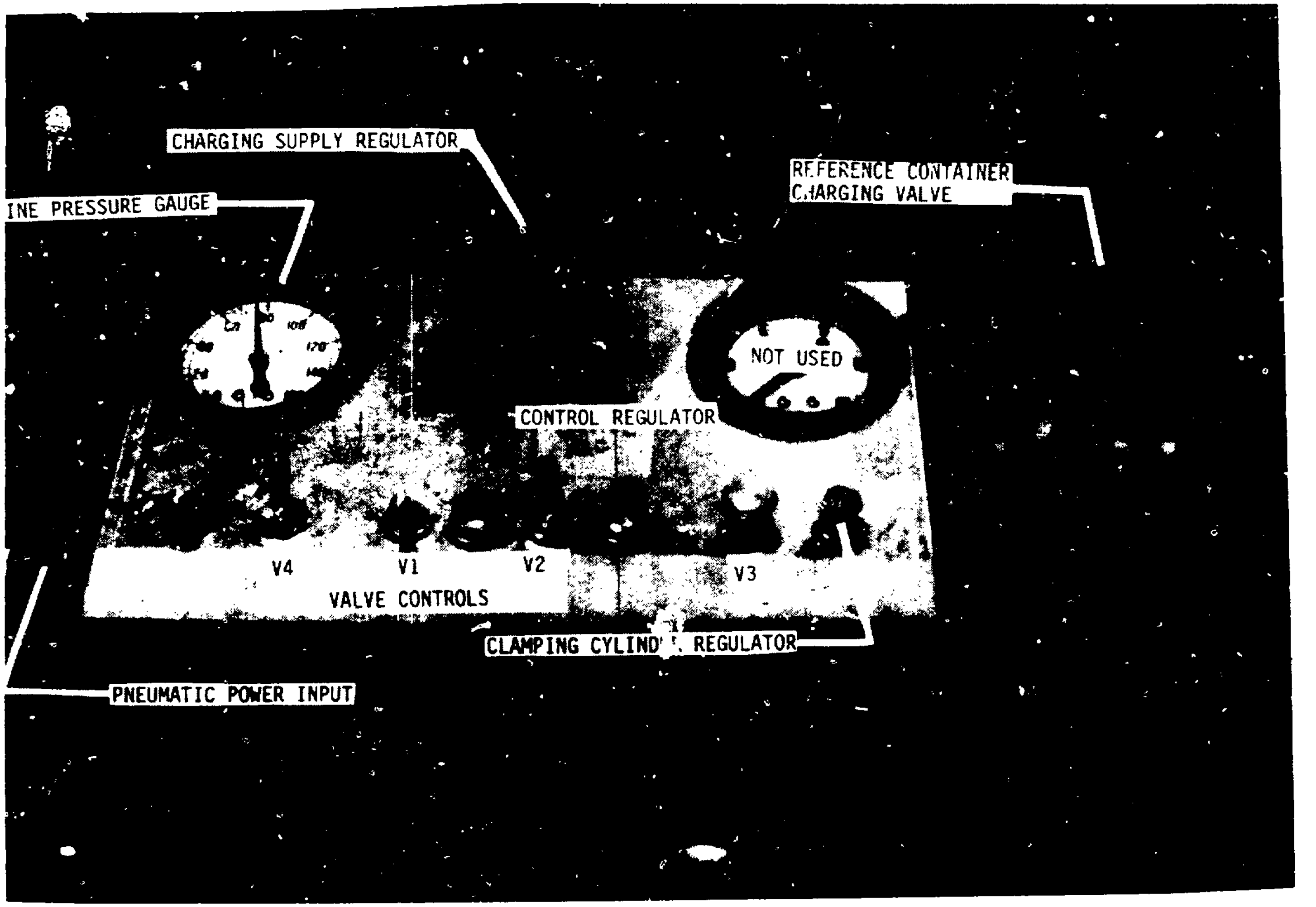

Figure 9. Detail of Control Box Functions

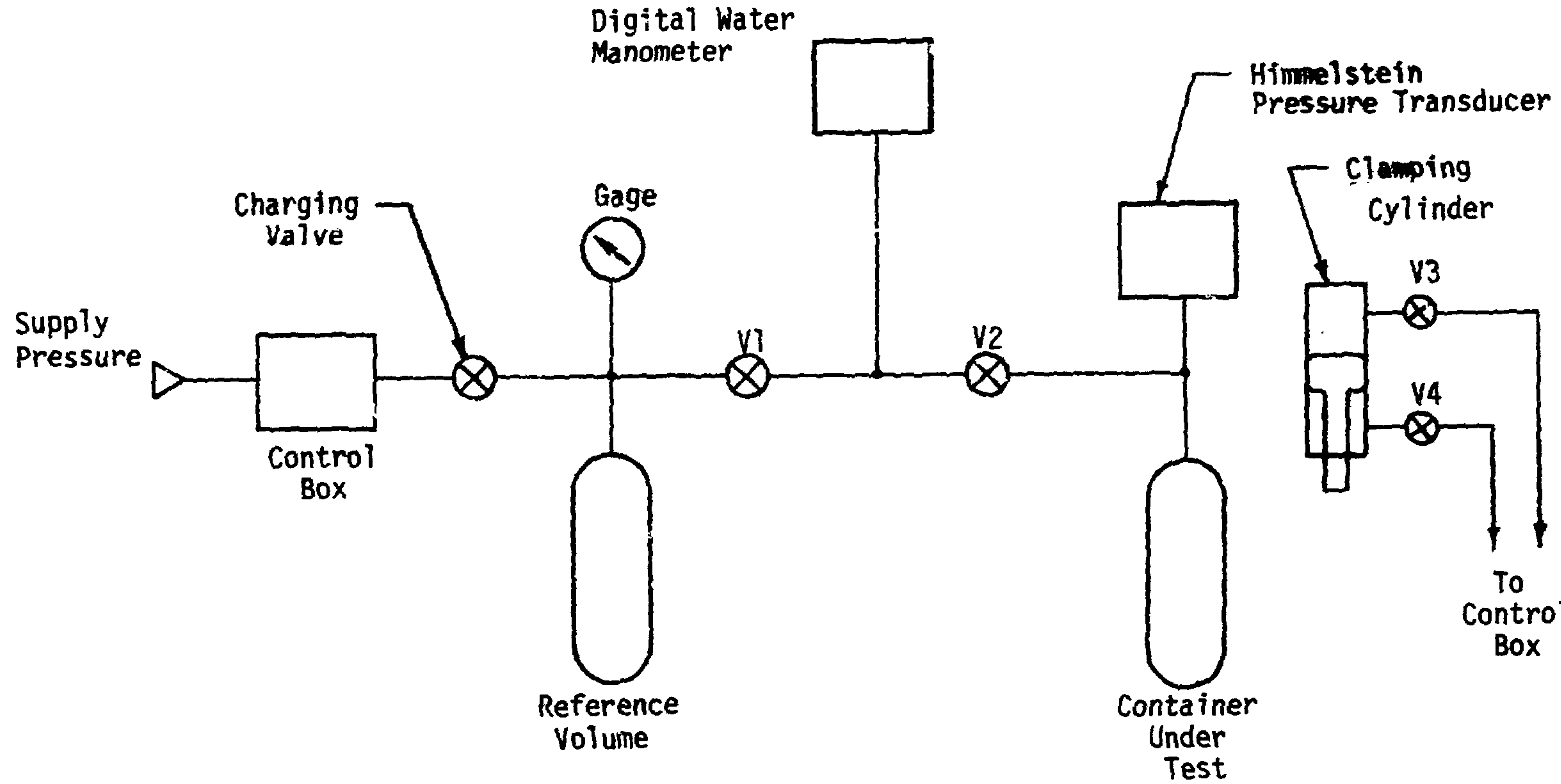

Figure 10. Schematic of Test Equipment Arrangement at Aberdeen Proving Ground

4. Turn on pneumatic power.
5. Adjust supply and control regulators.
6. Push clamping cylinder release valve (V3).
7. Turn on power to the clamping cylinder.
8. Open reference container charging valve.
9. Charge reference container to 17.2 to 41 kPa (2.5 to 6 psig), then close charging valve.
10. Number sequentially containers to be tested.
11. Reset all instrumentation.
12. Open supply valve (V1) and record the pressure after it has stabilized as P1.
13. Position test probe over the vent plug hole and clamp the test probe in place by actuating the clamping valve (V4).
14. Open the container valve (V2).
15. Allow the pressure to stabilize then record the pressure as P2.
16. Close the supply valve (V1).
17. Start the leak test instrumentation.
18. While the leak test is in progress (100 second duration) the following must be accomplished:
    A. Charge the reference container.
    B. Replace the vent plug on the previously tested container.
    C. Remove the vent plug from the next container to be tested.
    D. Check the lid torque on the previously tested container.
19. When the leak test is completed record the pressure remaining in the container as P3.
20. Close the container valve (V2).
21. Release the test probe by actuating the release valve (V3).
22. Return to Step 11, above, and repeat the sequence for the next container to be tested.

The data necessary for the determination of the container ullage volume was obtained in steps 12 through 15 above. Since the test arrangement represents a closed system we can use Boyle's Law to determine the ullage volume. Noting that Boyle's Law can be expressed as

$$P_1V_1 = P_2V_2 \tag{31}$$

for the conditions represented by the described test arrangement, we have

$$P_1 (V_R+V_L) = P_2 (V_R + V_L + V_U) \tag{32}$$

where P_1 = Pressure at the start of the ullage volume test.

P_2 = Pressure at the end of the ullage volume test.

V_R = Volume of the reference container.

V_L = Volume of the line connecting the reference and test containers.

V_u = Ullage volume in the container under test.

Solving Equation 32 for the ullage volume and rearranging the terms we have

$$V_u = (V_r + V_L) \left(\frac{P_1}{P_2} - 1\right) \tag{33}$$

The reference volume used in the testing was an empty M19A2 propellant charge container for which the volume had been determined to be 1377 cubic inches. The volume of the connecting line was also determined in the laboratory and was found to be less than 1% of the total system volume. Due to this minimal effect, the volume of the interconnecting line was ignored during the ullage volume calculations, and Equation 33 reduced to

$$V_u = V_r \left(\frac{P_1}{P_2} - 1\right) \tag{34}$$

A stabilization period was included in the test sequence and was required prior to the recording of any system pressure in order to minimize the introduction of errors due to the adiabatic heating/cooling caused by the pressurization or de-pressurization of the various volumes in the test arrangement.

The pressure transducer available for use with the Himmelstein leak detection equipment had a range of 0.0 to 344.7 kPa (0-50 psig) and had a sensitivity of $\pm$ 0.34 kPa ($\pm$ 0.05 psig). Early in the course of laboratory testing a comparison of the readings obtained from the Himmelstein equipment with those obtained from a water manometer indicated that the pressure transducer was not sufficiently sensitive

for measuring the small leakage rates encountered. Since there was insufficient time prior to the testing scheduled at APG for the purchase of a more sensitive transducer, the Himmelstein equipment was used only as a reference, and the readings from the water manometer were used for the leakage rate/hole size calculations.

During the course of the loaded container testing, a container exhibiting a large leakage rate which also did not meet the minim required lid torque of 2.6 kg-m (225 in-lb) was retested after th container lid was re-torqued to within specification to determine if the leakage was caused by the lid seal or the container.

Results of Testing

A total of 351 containers of various sizes and lots were tested at Aberdeen Proving Ground during the period of March 1979. The data obtained from these tests are presented in Figure 11 organized by lot number, propellant charge, and container type. The columns used in the figure are identified as follows:

ID - An arbitrarily assigned identification number

TORQ - The container lid torque in inch-pounds

P1 - Auxiliary container pressure at the start of the ullage volume test in inches of water.

P2 - Auxiliary container pressure at the end of the ullage volume test/container pressure at the start of the leakage test in inches of water.

P3 - Container pressure at the end of the leakage test in inches of water.

These data were then utilized as the input to the computer program shown in Figure 12, which calculated the container ullage volume, the effective leakage hole size and the statistical summaries for each container type, lot, and charge combination. Tables 1 through 9 present the results of the computer runs for each container type, lot and charge combination. Tables 10 and 11 present the combined data regardless of container lot for all the M14A2 containers with M3 charges and the PA66 containers with M138E1 charges, respectively.

During the conduct of the test, 17 containers exhibited no measurable lid torque and were not included in the previous statistical summary. The lids on these containers were re-torqued to within specification and then tested. The results of this test are presented in Table 12. Container ID #8 exhibited gross leakage. This condition could not be corrected by re-torquing the lid and the container was omitted from further testing. Container ID #12 did not have a sealing

LOT NUMBER	CHARGE	CONTAINER
RAD-67-627-1970	M3	M14A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
001	351.	131.0	092.0	092.0	002	351.	126.0	088.1	088.0
003	351.	120.0	083.0	082.6	004	351.	108.0	078.7	078.7
005	351.	145.0	105.9	105.7	006	351.	129.0	093.5	093.5
007	351.	116.7	085.8	085.6	011	351.	130.3	094.1	093.9
009	250.	128.6	094.0	093.8	010	351.	141.0	103.5	103.3

LOT NUMBER	CHARGE	CONTAINER
RAD-68-017-1971	M3	M14A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
014	260.	138.5	101.0	100.8	015	200.	129.8	095.6	093.0
016	250.	114.7	085.0	084.7	017	225.	145.7	106.6	106.4
018	240.	113.9	094.5	094.2	019	130.	146.3	106.3	098.9
020	200.	145.9	107.5	107.3	021	300.	132.8	096.0	095.1
022	250.	128.2	091.5	090.9	023	150.	150.0	111.6	101.0
024	200.	145.9	102.7	102.5	025	150.	141.8	100.3	099.9
026	250.	142.2	102.9	102.8	027	351.	122.6	094.7	094.5
028	240.	138.9	097.9	097.7	029	175.	132.0	095.0	094.0
030	175.	148.0	105.8	105.3	031	140.	142.0	101.9	101.7
032	210.	153.0	108.5	108.2	033	351.	135.0	096.8	096.6
034	230.	142.0	102.4	102.1	014	225.	132.7	098.6	098.3

Figure 11. Raw Test Data from Loaded Container Testing

LOT NUMBER	CHARGE	CONTAINER
IND-77A-569/164	M188F1M	PA66

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
036	351.	167.5	083.4	083.3	037	330.	150.9	075.3	075.3
038	351.	156.3	078.2	078.2	039	350.	160.9	088.1	088.1
040	340.	160.0	079.7	079.7	041	351.	160.1	080.3	080.3
042	240.	177.0	086.7	086.6	043	350.	179.2	088.6	088.4
044	340.	156.0	078.0	078.0	045	350.	171.5	085.3	084.0
046	351.	177.0	087.6	086.4	047	330.	157.0	079.4	079.3
048	280.	171.0	085.7	085.6	049	340.	165.0	082.7	082.7
050	275.	163.1	081.9	081.9	051	250.	166.0	082.4	082.3
052	340.	166.0	082.7	082.7	053	325.	170.9	085.6	085.5
054	310.	148.8	074.9	074.9	035	350.	170.0	082.9	077.3

LOT NUMBER	CHARGE	CONTAINER
RAD-69/11-0F76	M188E1	PA66

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
056	300.	162.4	085.0	085.0	057	300.	157.2	078.7	078.6
058	290.	184.0	091.1	090.9	059	290.	176.7	087.6	087.5
060	230.	170.3	083.4	083.3	061	330.	174.0	086.5	086.5
062	351.	182.0	088.5	088.3	063	330.	178.2	091.9	091.8
064	310.	165.9	082.1	082.1	065	230.	164.0	081.5	081.3
066	280.	182.3	089.5	089.4	067	330.	164.8	085.9	085.8
068	330.	153.9	077.3	077.2	069	300.	157.0	080.6	080.5
070	310.	159.7	079.1	079.0	071	320.	161.5	080.1	080.0
072	325.	171.0	084.2	084.0	073	330.	165.5	081.6	081.6
074	240.	151.3	075.0	074.8	055	351.	169.6	083.3	083.1
080	250.	175.8	088.3	087.0	081	300.	180.8	090.7	090.7
082	200.	157.9	078.1	075.8	083	190.	180.0	090.7	089.3
084	260.	176.8	088.7	088.7	079	300.	152.0	077.2	077.2

LOT NUMBER	CHARGE	CONTAINER
IND-77A-569/164	M188E1	PA66

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
076	150.	153.3	078.0	078.0	077	240.	165.7	086.1	086.1
078	225.	186.3	093.9	092.5	075	175.	171.9	086.7	086.[illegible]

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

LOT NUMBER CHARGE CONTAINER

CIL-67337 1969 M4A2 M13A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
103	075.	133.1	09[illegible].1	098.0	104	105.	126.1	093.2	093.2
105	225.	109.4	080.6	076.7	106	140.	117.9	087.2	086.7
107	140.	121.0	084.8	088.8	108	130.	111.0	081.8	080.7
109	190.	114.8	085.2	084.5	110	175.	088.9	066.3	066.1
111	240.	103.3	076.9	076.2	112	190.	105.3	078.1	077.3
113	300.	097.7	075.5	074.9	114	150.	115.7	085.5	084.8
115	325.	104.5	081.3	080.3	116	310.	101.2	076.5	076.1
117	250.	106.2	080.0	078.9	118	250.	113.5	084.5	084.1
119	150.	102.3	076.8	076.2	120	220.	102.6	077.1	076.7
121	200.	101.2	076.2	075.7	122	225.	093.3	070.7	066.9
123	100.	086.3	065.5	064.9	124	150.	112.1	083.4	082.7
125	230.	118.3	087.4	087.0	126	200.	107.3	079.1	075.4
127	220.	100.7	074.9	074.1	128	240.	118.0	087.1	078.9
129	180.	100.3	082.6	082.0	130	250.	106.9	078.2	056.7
131	240.	115.0	086.0	085.4	132	130.	106.3	079.9	079.3
133	351.	104.2	077.3	076.6	134	110.	117.9	087.5	086.9
135	290.	101.5	075.4	074.9	136	275.	098.5	073.2	072.8
137	230.	114.8	086.2	085.2	138	330.	096.7	072.3	071.8
139	250.	101.9	076.4	075.7	140	125.	110.0	082.0	080.9
141	180.	102.6	075.7	074.9	142	190.	103.8	077.7	077.1
143	225.	114.6	085.3	084.5	144	180.	119.3	088.1	087.2
145	350.	107.0	087.9	087.1	146	210.	112.7	084.7	081.9
147	150.	106.7	078.9	078.3	148	300.	111.4	084.7	083.9
149	200.	102.0	076.9	076.1	150	225.	092.7	070.2	069.8
151	180.	102.3	075.9	078.1	152	100.	129.0	096.0	094.4

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

LOT NUMBER CHARGE CONTAINER

CIL-67337 1969 M4A2 M13A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
153	351.	104.5	080.8	080.2	154	350.	107.5	080.5	079.8
155	120.	108.5	081.3	080.2	156	250.	109.4	081.3	080.8
157	225.	108.3	080.5	079.9	158	150.	105.9	079.9	078.9
159	200.	110.9	082.7	082.2	160	220.	097.3	073.5	072.9
161	351.	110.5	083.1	082.3	162	340.	106.1	079.3	078.3
163	225.	107.0	079.9	078.9	164	160.	107.6	079.9	078.6
165	175.	105.9	078.7	077.8	166	225.	096.3	072.7	071.9
167	175.	107.0	080.2	079.2	168	351.	114.0	086.1	085.3
169	351.	097.9	073.6	073.1	170	351.	097.7	073.6	072.9
171	175.	103.1	077.6	076.9	172	225.	109.9	083.2	082.7
173	150.	113.3	083.7	082.6	174	250.	101.1	076.1	075.3
175	300.	101.5	076.9	076.2	176	340.	114.2	085.0	084.1
177	230.	114.2	085.5	084.3	178	225.	107.9	080.7	079.7
179	350.	112.4	084.0	083.3	180	120.	106.2	080.2	079.4
181	250.	102.3	081.6	080.7	182	200.	085.1	066.5	066.0
183	175.	100.7	075.7	074.7	184	351.	131.2	096.5	095.6
185	350.	116.5	084.7	083.7	186	280.	109.3	083.7	083.1
187	180.	093.5	077.0	076.3	188	150.	104.0	077.3	076.7
189	210.	091.2	069.1	068.4	190	260.	110.3	081.7	081.0
191	230.	105.5	082.7	081.9	192	200.	104.0	077.7	076.7
193	300.	097.2	073.4	072.7	194	190.	100.5	075.9	074.7
195	250.	096.3	072.7	071.9	196	180.	097.2	073.7	073.0
197	240.	098.9	078.2	077.7	198	220.	108.7	080.3	079.0
199	220.	100.6	074.9	074.0	200	350.	097.3	074.1	073.2
201	300.	099.0	076.1	075.9	102	150.	135.4	100.3	099.5

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

LOT NUMBER CHARGE CONTAINER

BAJ-67778-OF1970 M1 M18A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
203	175.	096.6	066.4	066.3	204	160.	093.8	070.9	070.7
205	000.	089.5	062.7	062.7	206	200.	091.3	063.6	063.5
207	200.	106.9	074.3	074.3	208	190.	105.5	074.5	074.4
209	210.	097.5	068.0	068.0	210	180.	120.3	083.5	083.5
211	180.	110.7	081.6	081.5	212	180.	120.4	083.9	083.9
213	230.	119.6	084.0	083.7	214	170.	123.0	085.2	085.1
215	200.	123.6	085.3	085.3	216	130.	116.5	081.5	081.5
217	140.	130.5	089.9	089.9	218	175.	137.7	094.8	094.5
219	190.	123.5	085.6	085.6	220	160.	112.3	078.3	078.3
221	160.	117.7	081.9	081.7	222	190.	108.4	075.4	075.4
223	150.	141.9	097.7	097.5	224	120.	107.9	073.9	073.8
225	230.	113.7	079.2	079.1	226	180.	123.7	085.3	085.2
227	090.	128.8	091.5	091.3	228	180.	121.5	085.3	085.1
229	150.	107.4	081.9	081.8	230	200.	103.1	072.7	072.4
231	160.	107.0	073.4	073.3	232	160.	102.4	071.1	071.0
233	150.	107.8	077.7	077.5	234	150.	110.7	082.4	082.3
235	160.	116.8	080.9	080.7	236	170.	115.5	080.3	080.3
237	140.	114.5	079.4	079.2	238	240.	114.3	078.9	078.8
239	200.	107.3	074.8	074.7	240	140.	115.5	079.7	079.6
241	130.	108.9	077.8	077.7	242	230.	106.4	074.5	074.4
243	200.	107.1	074.7	074.5	244	175.	109.2	075.7	075.5
245	190.	105.4	073.5	073.3	246	210.	101.1	070.7	070.6
247	200.	108.2	075.2	075.1	248	190.	069.1	047.4	047.4
249	180.	105.8	073.2	073.1	250	100.	108.4	075.2	073.4
251	150.	092.3	063.6	063.5	252	150.	101.9	069.9	069.8

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

LOT NUMBER	CHARGE	CONTAINER
BAJ-67778-0F1970	M2	M18A2

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
253	351.	105.6	074.4	074.3	254	351.	101.1	070.7	070.5
255	351.	109.5	077.5	077.3	256	351.	104.7	072.3	072.2
257	351.	105.9	074.8	074.7	258	351.	105.3	074.5	074.5
259	351.	101.8	073.1	073.0	260	351.	064.5	046.6	046.5
261	351.	104.3	072.9	072.8	262	200.	109.4	075.7	075.5
263	250.	098.0	074.7	074.5	264	351.	096.3	075.2	075.1
265	351.	103.9	075.3	075.1	266	351.	097.3	074.5	074.4
267	351.	098.5	076.0	075.9	268	351.	103.2	076.6	076.5
269	351.	102.8	071.8	071.7	270	351.	102.5	072.3	072.1
271	351.	111.3	077.1	076.9	272	250.	090.3	065.3	045.4
273	351.	122.5	084.7	084.7	274	350.	095.2	073.6	073.5
275	351.	100.6	070.5	070.3	276	351.	103.1	072.2	072.0
277	220.	106.5	074.1	074.0	278	351.	119.0	085.1	084.9
279	351.	107.9	075.0	074.8	280	351.	096.4	067.8	067.7
281	351.	097.2	068.0	067.8	282	351.	106.4	073.4	073.3
283	351.	100.6	075.2	075.0	284	351.	111.5	077.1	076.9
285	351.	098.2	075.2	075.1	286	351.	103.6	078.9	078.7
287	300.	095.9	074.9	074.7	288	340.	102.5	080.1	080.0
289	351.	099.1	074.9	074.8	290	351.	098.7	074.9	074.7
291	351.	096.1	076.2	076.1	292	351.	112.9	078.2	078.0
293	351.	106.5	080.5	080.4	294	351.	096.8	076.[illegible]	076.7
295	340.	098.7	076.6	076.5	296	351.	094.1	075.2	075.0
297	351.	099.1	076.6	076.3	298	351.	100.5	077.2	077.0
299	351.	101.7	079.3	079.2	300	351.	101.5	079.8	079.7

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

LOT NUMBER CHARGE CONTAINER

IA-BR-35729-54 M2 M19A1

ID=	TORQ	P1	P2	P3	ID=	TORQ	P1	P2	P3
301	351.	098.5	073.6	073.4	302	351.	094.0	071.1	071.0
303	250.	122.5	052.7	052.4	304	200.	109.2	074.9	073.5
305	260.	112.9	078.1	077.7	306	180.	116.5	073.1	072.8
307	250.	122.8	060.4	060.1	308	280.	118.1	076.8	076.4
309	220.	132.5	061.1	060.9	310	300.	125.1	076.3	077.6
311	220.	118.6	073.5	073.5	312	260.	122.9	081.5	081.4
313	350.	113.1	068.9	068.8	314	200.	108.9	073.0	073.4
315	100.	129.0	073.4	047.4	316	275.	136.2	083.8	083.5
317	100.	112.9	075.9	075.6	318	200.	113.7	073.7	073.2
319	300.	119.6	077.1	076.3	320	275.	118.6	079.5	078.8
321	300.	121.7	060.6	060.3	322	300.	107.6	068.5	059.6
323	250.	131.0	063.7	063.1	324	351.	117.9	072.3	071.9
325	210.	114.1	070.7	070.4	326	260.	155.3	093.2	092.8
327	150.	125.5	075.1	075.5	328	275.	127.9	086.4	085.9
329	250.	121.5	070.3	074.8	330	240.	118.0	080.7	080.5
331	200.	116.1	077.[illegible]	077.2	332	150.	117.5	080.1	079.7
333	275.	128.3	065.4	065.0	334	180.	119.6	081.4	081.3
335	200.	119.3	062.5	062.4	336	240.	108.5	065.1	064.9
337	260.	112.6	070.8	070.5	338	300.	122.0	080.3	080.0
339	300.	125.2	075.6	075.1	340	230.	123.8	075.0	074.7
341	351.	129.0	077.5	077.1	342	300.	118.7	073.4	073.2
343	220.	124.5	075.5	075.3	344	250.	137.0	083.1	082.9
345	300.	114.0	070.3	070.2	346	260.	114.6	069.4	069.1
347	300.	115.9	072.0	071.9	348	230.	114.0	069.6	069.3
349	351.	120.1	072.3	071.1	350	310.	113.6	070.1	069.9
351	230.	123.2	063.7	063.3	352	260.	134.0	082.0	081.6

Figure 11. (Con't) Raw Test Data from Loaded Container Testing

```
      PROGRAM DATA(INPUT,OUTPUT,TAPE5,TAPE6=OUTPUT)
      DIMENSION ID(100),TOR(100),P1(100),P2(100),P3(100),
     +VULI(100),Q(100),D(100)
      TTV=0.
      TTQ=0.
      TTD=0.
      ITO=0
      ITU=0
      TTV2=0.
      TTQ2=0.
      TTD2=0.
      M=0
      READ(5,1) V1
60    READ(5,2) N,XLOT1,XLOT2,CHARGE,CONT
      IF(EOF(5)) 10,20
20    DO 30 I=1,N,2
30    READ(5,3) ID(I),TOR(I),P1(I),P2(I),P3(I),
     +ID(I+1),TOR(I+1),P1(I+1),P2(I+1),P3(I+1)
      TV=0.
      TQ=0.
      TD=0.
      IOBAD=0
      IUBAD=0
      TV2=0.
      TQ2=0.
      TD2=0.
      DO 40 I=1,N
      VULI(I)=((P1(I)/P2(I))-1.)*V1
      VULF=VULI(I)/1728.
      P1(I)=P1(I)/27.692
      P2(I)=P2(I)/27.692
      P3(I)=P3(I)/27.692
      Q(I)=((P2(I)-P3(I))*86.4*VULF)/2157.6866
      R=14.7/(P2(I)+14.7)
      D2=(Q(I)/(P2(I)+14.7))/(16.4435*SQRT(R*(1.-R)*(3.-R)))
      D(I)=SQRT(D2)
      TV=TV+VULI(I)
      TQ=TQ+Q(I)
      TD=TD+D(I)
```

Figure 12 Data Reduction Computer Program

```
      IF(TOR(I).GT.350.) IOBAD=IOBAD+1
      IF(TOR(I).LT.225.) IUBAD=IUBAD+1
      TV2=TV2+(VULI(I)**2)
      TQ2=TQ2+(Q(I)**2)
40    TD2=TD2+(D(I)**2)
      TTV=TTV+TV
      TTQ=TTQ+TQ
      TTD=TTD+TD
      ITO=ITO+IOBAD
      ITU=ITU+IUBAD
      TTV2=TTV2+TV2
      TTQ2=TTQ2+TQ2
      TTD2=TTD2+TD2
      M=M+N
      VAV6=TV/N
      QAV6=TQ/N
      DAV6=TD/N
      VARV=(N*TV2-(TV**2))/(N*(N-1))
      VARQ=(N*TQ2-(TQ**2))/(N*(N-1))
      VARD=(N*TD2-(TD**2))/(N*(N-1))
      WRITE(6,4) CONT,XLOT1,XLOT2,CHARGE
      WRITE(6,5)
      DO 50 I=1,N
      IF(I.EQ.33.OR.I.EQ.65.OR.I.EQ.97) GO TO 70
      GO TO 80
70    WRITE(6,5)
80    CONTINUE
50    WRITE(6,6) ID(I),TOR(I),VULI(I),Q(I),D(I)
      WRITE(6,7) VAV6,VARV,QAV6,VARQ,DAV6,VARD,N,IUBAD,IOBAD
      GO TO 60
10    TVAV6=TTV/M
      TQAV6=TTQ/M
      TDAV6=TTD/M
      VARTT=(M*TTT2-(TTT**2))/(M*(M-1))
      VARTV=(M*TTV2-(TTV**2))/(M*(M-1))
      VARTQ=(M*TTQ2-(TTQ**2))/(M*(M-1))
      VARTD=(M*TTD2-(TTD**2))/(M*(M-1))
      WRITE(6,8) TQAV6,VARTQ,TDAV6,VARTD,M,ITU,ITO
1     FORMAT(F8.0)
2     FORMAT(I3,A10,A10,A10,A10)
```

Figure 12. (Con't) Data Reduction Computer Program

```
3     FORMAT(I3,1X,F4.0,2X,F5.0,1X,F5.0,1X,F5.0,1X,I3,1X,F4.0,
     +2X,F5.0,1X,F5.0,1X,F5.0)
4     FORMAT(1H1,//,10X,17HCONTAINER TYPE-   ,A10,/,10X,
     +17HCONTAINER LOT--   ,A10,A10,/,10X,
     +17HCHARGE TYPE   --   ,A10)
5     FORMAT(//,33X,9HEFFECTIVE,/,6X,3HLID,4X,6HULLAGE,
     +6X,4HFLOW,6X,4HHOLE,/,1X,3HS/N,1X,6HTORQUE,2X,6HVOLUME,
     +5X,6H(SCFM),3X,13HDIAMETER (IN),/,1X,69(1H*),/)
6     FORMAT(1X,I3,1X,F6.1,1X,F9.3,2(1X,F10.7))
7     FORMAT(///,1X,19HSTATISTICAL SUMMARY,4X,4HMEAN,10X,
     +8HVARIANCE,//,1X,13HULLAGE VOLUME,5X,F10.4,5X,F11.4,/,
     +1X,11HFLOW (SCFM),7X,F10.7,5X,F13.10,/,1X,
     +14HHOLE SIZE (IN),4X,F10.7,5X,F13.10,//1X,9HTOTAL OF ,
     +I3,20H CONTAINERS TESTED: ,I3,14H UNDER TORQUED ,
     +/,33X,I3,13H OVER TORQUED )
8     FORMAT(///,1X,5HTOTAL,/,1X,19HSTATISTICAL SUMMARY,4X,4HMEAN
     +,10X,8HVARIANCE,//,11HFLOW (SCFM),7X,F10.7,5X,F13.10,
     +/,1X,14HHOLE SIZE (IN),4X,F10.7,5X,F13.10,//,1X,
     +9HTOTAL OF ,I3,20H CONTAINERS TESTED: ,I3,
     +14H UNDER TORQUED,/,33X,I3,13H OVER TORQUED )
      STOP
      END
```

Figure 12. (Con't) Data Reduction Computer Program

Table 1. Leakage and Ullage Volume Results - M14A2 Container, M3 Charge

CONTAINER TYPE- M14A2
CONTAINER LOT-- RAD-67-627-1970
CHARGE TYPE -- M3

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
1	351.0	583.728	0.0000000	0.0000000
2	351.0	592.376	.0000496	.0005465
3	351.0	613.843	.0002055	.0011305
4	351.0	512.657	0.0000000	0.0000000
5	351.0	508.411	.0000851	.0006816
6	351.0	522.818	0.0000000	0.0000000
7	351.0	495.913	.0000830	.0007122
11	351.0	529.728	.0000887	.0007182
9	250.0	506.853	.0000848	.0007027
10	351.0	498.913	.0000835	.0006794

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	536.5240	1873.7996
FLOW (SCFM)	.0000680	.0000000038
HOLE SIZE (IN)	.0005171	.0000001495

TOTAL OF 10 CONTAINERS TESTED: 0 UNDER TORQUED
9 OVER TORQUED

Table 2. Leakage and Ullage Volume Results - M14A2 Container, M3 Charge

CONTAINER TYPE- M14A2
CONTAINER LOT-- RAD-68-017-1971
CHARGE TYPE -- M3

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
14	260.0	511.262	.0000856	.0006923
15	200.0	492.609	.0010718	.0024864
16	250.0	481.140	.0001208	.0008613
17	225.0	505.072	.0000845	.0005782
18	240.0	282.686	.0000710	.0006418
19	130.0	518.156	.0032086	.0041815
20	200.0	491.877	.0000823	.0006678
21	300.0	527.850	.0003975	.0015126
22	250.0	552.305	.0002773	.0012797
23	150.0	547.839	.0048594	.0050791
24	200.0	579.225	.0000969	.0007336
25	150.0	569.746	.0001907	.0010354
26	250.0	525.910	.0000440	.0004940
27	351.0	405.684	.0000679	.0006274
28	240.0	556.926	.0005593	.0017798
29	175.0	536.305	.0004488	.0016117
30	175.0	549.238	.0002298	.0011205
31	140.0	541.881	.0000907	.0007110
32	210.0	564.760	.0001418	.0008742
33	351.0	543.403	.0000909	.0007219
34	230.0	532.512	.0001337	.0008621
13	225.0	476.224	.0001196	.0008236

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	513.3905	4154.1465
FLOW (SCFM)	.0005669	.0000013786
HOLE SIZE (IN)	.0013399	.0000013770

TOTAL OF 22 CONTAINERS TESTED: 10 UNDER TORQUED
2 OVER TORQUED

Table 3. Leakage and Ullage Volume Results - PA66 Container, M188E1M Charge

CONTAINER TYPE- PA66
CONTAINER LOT-- IND-77A-S69716A
CHARGE TYPE -- M188E1M

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
36	351.0	1388.558	.0001162	.0008491
37	330.0	1382.486	0.0000000	0.0000000
38	351.0	1375.239	0.0000000	0.0000000
39	350.0	1137.862	0.0000000	0.0000000
40	340.0	1387.366	0.0000000	0.0000000
41	351.0	1368.426	0.0000000	0.0000000
42	240.0	1434.176	.0001200	.0008540
43	350.0	1408.084	.0002357	.0011898
44	340.0	1377.000	0.0000000	0.0000000
45	350.0	1391.529	.0015138	.0030463
46	351.0	1405.295	.0014112	.0029205
47	330.0	1345.783	.0001126	.0008469
48	280.0	1370.573	.0001147	.0008375
49	340.0	1370.340	0.0000000	0.0000000
50	275.0	1365.231	0.0000000	0.0000000
51	250.0	1397.053	.0001169	.0008544
52	340.0	1386.990	0.0000000	0.0000000
53	325.0	1372.174	.0001148	.0008382
54	310.0	1358.615	0.0000000	0.0000000
35	350.0	1446.764	.0067797	.0064961

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	1373.4772	3655.9260
FLOW (SCFM)	.0005318	.0000023541
HOLE SIZE (IN)	.0009366	.0000025358

TOTAL OF 20 CONTAINERS TESTED: 0 UNDER TORQUED
4 OVER TORQUED

Table 4. Leakage and Ullage Volume Results - PA66 Container, M188E1 Charge

CONTAINER TYPE-   PA66
CONTAINER LOT--   RAD-69711-DF76
CHARGE TYPE ---   M188E1

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
56	300.0	1253.880	0.0000000	0.0000000
57	300.0	1373.501	.0001149	.0008576
58	290.0	1404.207	.0002350	.0011794
59	230.0	1400.579	.0001172	.0008416
60	230.0	1434.788	.0001201	.0008631
61	330.0	1392.919	0.0000000	0.0000000
62	351.0	1454.797	.0002435	.0012095
63	330.0	1293.091	.0001082	.0007994
64	310.0	1405.513	0.0000000	0.0000000
65	280.0	1393.896	.0002333	.0012105
66	280.0	1427.772	.0001195	.0008449
67	330.0	1264.788	.0001058	.0008040
68	330.0	1364.530	.0001142	.0008539
69	300.0	1305.246	.0001092	.0008307
70	310.0	1403.113	.0001174	.0008656
71	320.0	1399.345	.0001171	.0008616
72	325.0	1419.520	.0002376	.0012110
73	330.0	1415.813	0.0000000	0.0000000
74	240.0	1400.968	.0002345	.0012406
55	351.0	1426.592	.0002388	.0012175
80	250.0	1364.524	.0014844	.0029889
81	300.0	1367.891	0.0000000	0.0000000
82	200.0	1406.973	.0015306	.0031359
83	190.0	1355.745	.0015383	.0030697
84	260.0	1367.685	0.0000000	0.0000000
79	300.0	1334.192	0.0000000	0.0000000

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	1378.1450	2628.9372
FLOW (SCFM)	.0002757	.0000002224
HOLE SIZE (IN)	.0009573	.0000008111

TOTAL OF 26 CONTAINERS TESTED: 2 UNDER TORQUED
2 OVER TORQUED

Table 5. Leakage and Ullage Volume Results - PA66 Container, M188E1 Charge

CONTAINER TYPE- PA66
CONTAINER LOT-- IND-77A-S69716A
CHARGE TYPE -- M188E1

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
76	150.0	1329.335	0.0000000	0.0000000
77	240.0	1273.045	0.0000000	0 [illegible]00000
78	225.0	1355.003	.0015874	[illegible]30406
75	175.0	1353.176	.0001132	.0008296

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	1327.6399	1461.4364
FLOW (SCFM)	.0004252	.0000006032
HOLE SIZE (IN)	.0009675	.0000020629

TOTAL OF 4 CONTAINERS TESTED: 2 UNDER TORQUED
0 OVER TORQUED

Table 6. Leakage and Ullage Volume Results - M13A2 Container, M4A2 Charge

CONTAINER TYPE- M13A2
CONTAINER LOT-- CIL-67337
CHARGE TYPE -- M4A2

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
103	75.0	472.432	.0004349	.0015686
104	105.0	486.087	0.0000000	0.0000000
105	225.0	492.030	.0016058	.0031852
106	140.0	484.792	.0002028	.0011086
107	140.0	478.423	.0004003	.0015453
108	130.0	491.545	.0004525	.0016841
109	190.0	478.394	.0002802	.0013111
110	175.0	469.385	.0000786	.0007419
111	240.0	472.728	.0002769	.0013393
112	190.0	479.570	.0003210	.0014362
113	300.0	404.893	.0002033	.0011532
114	150.0	486.379	.0002849	.0013208
115	325.0	392.945	.0003289	.0014381
116	310.0	444.600	.0001488	.0009832
117	250.0	450.967	.0004151	.0016227
118	250.0	472.580	.0001582	.0009872
119	150.0	457.207	.0002296	.0012199
120	220.0	455.428	.0001524	.0009931
121	200.0	451.772	.0001890	.0011093
122	225.0	440.173	.0013997	.0030790
123	100.0	437.276	.0002196	.0012443
124	150.0	473.860	.0002776	.0013123
125	230.0	496.834	.0001630	.0009930
126	200.0	490.915	.0015200	.0031145
127	220.0	474.320	.0003175	.0014443
128	240.0	488.511	.0033521	.0045080
129	130.0	295.071	.0001482	.0009612
130	250.0	505.370	.0040923	.0076405
131	240.0	464.337	.0002331	.0011929
132	130.0	454.979	.0002284	.0012042
133	351.0	479.189	.0002807	.0013466
134	110.0	478.409	.0002402	.0012053

Table 6. (Con't) Leakage and Ullage Volume Results
M13A2 Container, M4A2 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
135	290.0	476.654	.0001994	.0011426
136	275.0	475.930	.0001593	.0010292
137	230.0	456.870	.0003823	.0015266
138	330.0	464.714	.0001944	.0011408
139	250.0	459.601	.0002692	.0013229
140	125.0	470.195	.0004328	.0016461
141	180.0	489.317	.0003276	.0014628
142	190.0	462.544	.0002322	.0012232
143	225.0	472.991	.0003166	.0013932
144	180.0	487.655	.0003673	.0014876
145	350.0	299.212	.0002003	.0010993
146	210.0	455.207	.0010666	.0025619
147	150.0	485.179	.0002436	.0012477
148	300.0	434.072	.0002906	.0013372
149	200.0	449.450	.0003009	.0013961
150	225.0	441.346	.0001477	.0010022
151	180.0	408.388	.0002734	.0013218
152	100.0	473.344	.0006338	.0019099
153	351.0	403.897	.0002028	.0011312
154	350.0	461.851	.0002705	.0013078
155	120.0	460.694	.0004241	.0016331
156	250.0	475.937	.0001991	.0011191
157	225.0	475.535	.0002388	.0012286
158	150.0	448.085	.0003750	.0015428
159	[illegible]	469.545	.0001965	.0011065
160	[illegible]	445.886	.0002239	.0012188
161	351.0	454.029	.0003039	.0013746
162	340.0	465.367	.0003894	.0015754
163	225.0	467.043	.0003908	.0015751
164	16[illegible].0	477.383	.0005193	.0018156
165	17[illegible]	475.914	.0003584	.0015144
166	2[illegible].0	447.004	.0002992	.0014132

Table 6. (Con't) Leakage and Ullage Volume Results
M13A2 Container, M4A2 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
167	175.0	460.145	.0003851	.0015618
168	351.0	446.205	.0002997	.0013499
169	351.0	454.635	.0001902	.0011231
170	351.0	450.893	.0002641	.0013233
171	175.0	452.494	.0002651	.0013072
172	225.0	441.898	.0001849	.0010717
173	150.0	486.968	.0004482	.0016661
174	250.0	452.365	.0003028	.0014045
175	300.0	440.497	.0002580	.0012929
176	340.0	473.040	.0003563	.0014792
177	230.0	462.221	.0004641	.0016858
178	225.0	464.119	.0003884	.0015660
179	350.0	465.557	.0002727	.0012983
180	120.0	446.409	.0002988	.0013759
181	250.0	349.313	.0002631	.0012850
182	200.0	385.146	.0001611	.0010618
183	175.0	454.756	.0003805	.0015766
184	351.0	495.149	.0003729	.0014630
185	350.0	516.985	.0004326	.0016316
186	280.0	421.161	.0002115	.0011443
187	180.0	295.071	.0001728	.0010579
188	150.0	475.626	.0002388	.0012421
189	210.0	440.401	.0002580	.0013299
190	260.0	492.034	.0002824	.0013309
191	230.0	379.632	.0002541	.0012585
192	200.0	466.089	.0003900	.0015852
193	300.0	446.493	.0002615	.0013179
194	190.0	446.300	.0004482	.0017095
195	250.0	447.004	.0002992	.0014132
196	180.0	439.071	.0002572	.0013054
197	240.0	364.500	.0001525	.0009895
198	220.0	487.009	.0005298	.0019314

Table 6. (Con't) Leakage and Ullage Volume Results
M13A2 Container, M4A2 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
199	220.0	472.482	.0003558	.0015289
200	350.0	431.126	.0003247	.0014646
201	300.0	414.367	.0000693	.0006721
102	150.0	481.881	.0003226	.0013467

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	453.7128	1582.0883
FLOW (SCFM)	.0004488	.0000009138
HOLE SIZE (IN)	.0014785	.0000006634

TOTAL OF 100 CONTAINERS TESTED: 49 UNDER TORQUED
7 OVER TORQUED

Table 7. Leakage and Ullage Volume Results - M18A2 Container, M1 Charge

CONTAINER TYPE- M18A2
CONTAINER LOT-- BAJ-67778-OF1970
CHARGE TYPE -- M1

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
203	175.0	626.286	.0000524	.0006058
204	160.0	444.757	.0000744	.0007095
205	0.0	588.574	0.0000000	0.0000000
206	200.0	599.731	.0000502	.0005996
207	200.0	604.175	0.0000000	0.0000000
208	190.0	574.828	.0000481	.0005629
209	210.0	597.375	0.0000000	0.0000000
210	180.0	606.869	0.0000000	0.0000000
211	180.0	592.312	.0000496	.0005578
212	180.0	599.052	0.0000000	0.0000000
213	230.0	583.586	.0001465	.0009516
214	170.0	610.923	.0000511	.0005600
215	200.0	618.278	0.0000000	0.0000000
216	130.0	591.350	0.0000000	0.0000000
217	140.0	621.871	0.0000000	0.0000000
218	175.0	623.136	.0001564	.0009521
219	190.0	609.676	0.0000000	0.0000000
220	160.0	597.931	0.0000000	0.0000000
221	160.0	601.912	.0001007	.0007944
222	190.0	602.666	0.0000000	0.0000000
223	150.0	622.962	.0001043	.0007710
224	120.0	633.532	.0000530	.0005922
225	230.0	599.830	.0000502	.0005659
226	180.0	619.892	.0000519	.0005639
227	90.0	561.334	.0000939	.0007448
228	180.0	584.377	.0000978	.0007743
229	150.0	428.736	.0000359	.0004741
230	200.0	575.802	.0001446	.0009822
231	160.0	630.343	.0000527	.0005918
232	160.0	606.190	.0000507	.0005853
233	150.0	533.432	.0000893	.0007584
234	150.0	472.926	.0000396	.0004971

Table 7. (Con't) Leakage and Ullage Volume Results - M18A2 Container, M1 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
235	160.0	611.054	.0001023	.0008030
236	170.0	603.616	0.0000000	0.0000000
237	140.0	608.724	.0001019	.0008055
238	240.0	617.817	.0000517	.0005748
239	200.0	598.295	.0000501	.0005737
240	140.0	618.527	.0000518	.0005736
241	130.0	550.446	.0000461	.0005446
242	230.0	589.615	.0000493	.0005701
243	200.0	597.253	.0001000	.0008109
244	175.0	609.373	.0001020	.0008162
245	190.0	597.637	.0001000	.0008147
246	210.0	592.091	.0000495	.0005793
247	200.0	604.269	.0000506	.0005757
248	190.0	630.399	0.0000000	0.0000000
249	180.0	613.254	.0000513	.0005842
250	100.0	607.931	.0009157	.0024500
251	150.0	621.382	.0000520	.0006103
202	150.0	630.386	.0000528	.0005995

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	593.3343	1771.2261
FLOW (SCFM)	.0000704	.0000000167
HOLE SIZE (IN)	.0005296	.0000001769

TOTAL OF 50 CONTAINERS TESTED: 46 UNDER TORQUED
0 OVER TORQUED

Table 8. Leakage and Ullage Volume Results - M18A2 Container, M2 Charge

CONTAINER TYPE- M19A2
CONTAINER LOT-- BAJ-67778-DF1970
CHARGE TYPE -- M2

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
253	351.0	577.452	.0000483	.0005644
254	351.0	592.091	.0000991	.0008193
255	351.0	568.568	.0000952	.0007835
256	351.0	617.079	.0000516	.0005879
257	351.0	572.523	.0000479	.0005612
258	351.0	569.283	0.0000000	0.0000000
259	351.0	540.628	.0000452	.0005487
260	351.0	528.933	.0000443	.0006109
261	351.0	593.111	.0000496	.0005751
262	200.0	613.011	.0001026	.0008186
263	250.0	429.506	.0000719	.0006877
264	351.0	386.366	.0000323	.0004604
265	351.0	506.546	.0000848	.0007452
266	351.0	421.417	.0000353	.0004820
267	351.0	407.664	.0000341	.0004716
268	351.0	478.175	.0000400	.0005097
269	351.0	594.526	.0000498	.0005781
270	351.0	575.178	.0000963	.0008027
271	351.0	610.809	.0001022	.0008132
272	250.0	653.706	.0108859	.0087689
273	351.0	614.529	0.0000000	0.0000000
274	350.0	404.120	.0000338	.0004735
275	351.0	587.911	.0000984	.0008170
276	351.0	589.325	.0000986	.0008128
277	220.0	602.039	.0000504	.0005769
278	351.0	548.535	.0000918	.0007507
279	351.0	604.044	.0001011	.0008146
280	351.0	580.858	.0000486	.0005802
281	351.0	591.300	.0000990	.0008272
282	351.0	619.087	.0000518	.0005865
283	351.0	465.104	.0000778	.0007143
284	351.0	614.381	.0001028	.0008156

Table 8. (Con't) Leakage and Ullage Volume Results - M18A2 Container, M2 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
285	351.0	421.157	.0000352	.0004807
286	351.0	431.076	.0000721	.0006790
287	300.0	386.075	.0000646	.0006515
288	340.0	385.079	.0000322	.0004520
289	351.0	444.905	.0000372	.0004945
290	351.0	437.551	.0000732	.0006936
29'	351.0	359.610	.0000301	.0004426
292	351.0	611.022	.0001023	.0008103
293	351.0	444.745	.0000372	.0004851
294	351.0	358.594	.0000300	.0004410
295	340.0	397.281	.0000332	.0004645
296	351.0	346.081	.0000579	.0006162
297	351.0	404.471	.0001015	.0008119
298	351.0	415.597	.0000696	.0006706
299	351.0	388.963	.0000325	.0004555
300	351.0	374.447	.0000313	.0004461

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	505.5106	9186.0616
FLOW (SCFM)	.0002856	.0000024425
HOLE SIZE (IN)	.0007719	.0000014238

TOTAL OF 48 CONTAINERS TESTED: 2 UNDER TORQUED
40 OVER TORQUED

Table 9. Leakage and Ullage Volume Results - M19A1 Container M2 Charge

CONTAINER TYPE- M19A1
CONTAINER LOT-- IA-BR-35729-54
CHARGE TYPE -- M2

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
301	351.0	348.630	.0000583	.0006112
252	351.0	443.506	.0000371	.0005006
303	250.0	662.692	.0001664	.0010182
304	200.0	630.589	.0007388	.0022030
305	260.0	613.567	.0002054	.0011487
306	180.0	817.535	.0002052	.0011686
307	250.0	726.179	.0001823	.0010739
308	280.0	740.496	.0002479	.0012676
309	220.0	872.723	.0001461	.0009591
310	300.0	823.034	.0004821	.0017588
311	220.0	844.935	0.0000000	0.0000000
312	260.0	699.341	.0002884	.0013442
313	350.0	883.358	.0000739	.0007124
314	290.0	652.165	.0002729	.0013436
315	100.0	1046.370	.0226784	.0122757
316	275.0	861.036	.0002162	.0011566
317	100.0	671.265	.0001685	.0010485
318	200.0	747.354	.0003127	.0014394
319	300.0	759.047	.0005081	.0018131
320	275.0	680.706	.0003987	.0015930
321	300.0	702.167	.0001763	.0010553
322	300.0	785.996	.0059538	.0063496
323	250.0	778.161	.0003907	.0015555
324	351.0	868.481	.0002907	.0013949
325	210.0	845.287	.0002122	.0011989
326	260.0	917.508	.0003071	.0013401
327	150.0	893.874	.0003740	.0015608
328	275.0	661.406	.0002767	.0012981
329	250.0	706.506	.0002956	.0013680
330	240.0	636.457	.0001065	.0008201
331	200.0	685.835	.0001722	.0010539
332	150.0	642.944	.0002152	.0011680

Table 9. (Con't) Leakage and Ullage Volume Results - M19A1 Container M2 Charge

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
333	275.0	691.725	.0002315	.0011910
334	180.0	649.592	.0000544	.0005845
335	200.0	614.225	.0000514	.0005663
336	240.0	918.000	.0001536	.0010426
337	260.0	929.669	.0002334	.0012568
338	300.0	715.080	.0001795	.0010661
339	300.0	903.429	.0003780	.0015719
340	230.0	895.968	.0002249	.0012151
341	351.0	915.039	.0003063	.0014057
342	300.0	849.838	.0001422	.0009718
343	220.0	893.682	.0001496	.0009891
344	250.0	893.144	.0001495	.0009640
345	300.0	855.973	.0000716	.0006976
346	260.0	896.836	.0002251	.0012410
347	300.0	839.587	.0000703	.0006865
348	230.0	878.431	.0002205	.0012272
349	351.0	910.382	.0009142	.0024737
350	310.0	858.415	.0001437	.0009887
351	230.0	649.839	.0002175	.0011606
302	260.0	886.654	.0002968	.0013631

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	774.7049	17558.6690
FLOW (SCFM)	.0007783	.0000102208
HOLE SIZE (IN)	.0014858	.0000030089

TOTAL OF 52 CONTAINERS TESTED: 15 UNDER TORQUED
5 OVER TORQUED

Table 10. Combined Results for the M14A2 Container with M3 Charge

CONTAINER TYPE- M14A2
CONTAINER LOT-- COMBINED
CHARGE TYPE -- M3

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
1	351.0	583.728	0.0000000	0.0000000
2	351.0	592.376	.0000496	.0005465
3	351.0	613.843	.0002055	.0011365
4	351.0	512.657	0.0000000	0.0000000
5	351.0	508.411	.0000851	.0006816
6	351.0	522.818	0.0000000	0.0000000
7	351.0	495.913	.0000830	.0007122
11	351.0	529.728	.0000887	.0007182
9	250.0	506.853	.0000848	.0007027
10	351.0	498.913	.0000835	.0006794
14	260.0	511.262	.0000856	.0006923
15	200.0	492.609	.0010718	.0024864
16	250.0	481.140	.0001208	.0008613
17	225.0	505.072	.0000845	.0006782
18	240.0	285.686	.0000710	.0006418
19	130.0	518.156	.0032086	.0041815
20	200.0	491.877	.0000823	.0006678
21	300.0	527.850	.0003975	.0015126
22	250.0	552.305	.0002773	.0012797
23	150.0	547.839	.0048594	.0050791
24	200.0	579.225	.0000969	.0007336
25	150.0	569.746	.0001907	.0010354
26	250.0	525.910	.0000440	.0004940
27	351.0	405.684	.0000679	.0006274
28	240.0	556.926	.0005593	.0017798
29	175.0	535.305	.0004488	.0016117
30	175.0	549.238	.0002298	.0011205
31	140.0	541.861	.0000907	.0007110
32	210.0	564.760	.0001418	.0008742
33	351.0	543.403	.0000909	.0007219
34	230.0	532.512	.0001337	.0008621
13	225.0	476.224	.0001196	.0008236

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	520.5578	3477.7154
FLOW (SCFM)	.0004110	.0000009902
HOLE SIZE (IN)	.0010927	.0000011263

TOTAL OF 32 CONTAINERS TESTED: 10 UNDER TORQUED
11 OVER TORQUED

Table 11. Combined Results for the PA66 Container with M188E1 Charge

CONTAINER TYPE- PA66
CONTAINER LOT-- COMBINED
CHARGE TYPE -- M188E1

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
56	300.0	1253.880	0.0000000	0.0000000
57	300.0	1373.501	.0001149	.0008576
58	290.0	1404.207	.0002350	.0011794
59	290.0	1400.579	.0001172	.0008416
60	230.0	1434.788	.0001201	.0008631
61	330.0	1392.919	0.0000000	0.0000000
~~62~~	351.0	1454.797	.0002435	.0012098
63	350.0	1293.091	.0001082	.0007984
64	310.0	1405.513	0.0000000	0.0000000
65	280.0	1393.896	.0002333	.0012105
66	280.0	1427.772	.0001195	.0008449
67	330.0	1264.788	.0001058	.0008040
68	330.0	1364.530	.0001142	.0008599
69	300.0	1305.246	.0001092	.0008307
70	310.0	1403.113	.0001174	.0008656
71	320.0	1399.348	.0001171	.0008616
72	325.0	1419.520	.0002376	.0012110
73	330.0	1415.813	0.0000000	0.0000000
74	240.0	1400.860	.0002345	.0012406
55	351.0	1426.592	.0002388	.0012175
80	250.0	1364.524	.0014844	.0029889
81	300.0	1367.891	0.0000000	0.0000000
82	200.0	1406.973	.0015306	.0031359
83	190.0	1355.745	.0015883	.0030697
84	260.0	1367.685	0.0000000	0.0000000
79	300.0	1234.192	0.0000000	0.0000000
76	150.0	1329.335	0.0000000	0.0000000
77	240.0	1273.045	0.0000000	0.0000000
78	225.0	1355.003	.0015874	.0030406
75	175.0	1353.176	.0001132	.0008296

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	1371.4110	2722.4276
FLOW (SCFM)	.0002957	.0000002568
HOLE SIZE (IN)	.0009587	.0000009126

TOTAL OF 30 CONTAINERS TESTED: 4 UNDER TORQUED
2 OVER TORQUED

Table 12. Results of Container Testing After Lid Re-Torque

CONTAINER TYPE- PA66
CONTAINER LOT-- IND-77A-569716,
CHARGE TYPE -- M188E1

S/N	LID TORQUE	ULLAGE VOLUME	FLOW (SCFM)	EFFECTIVE HOLE DIAMETER (IN)
85	300.0	1383.859	.0002316	.0012109
86	300.0	1318.235	0.0000000	0.0000000
87	300.0	1346.824	0.0000000	0.0000000
88	300.0	1331.318	.0001114	.0008288
89	300.0	1314.929	0.0000000	0.0000000
90	300.0	1341.272	0.0000000	0.0000000
91	300.0	1328.215	.0001111	.0008199
92	300.0	1430.153	0.0000000	0.0000000
93	300.0	1296.202	.0014101	.0029898
94	300.0	1257.191	0.0000000	0.0000000
95	300.0	1388.741	0.0000000	0.0000000
96	300.0	1350.927	0.0000000	0.0000000
97	300.0	1358.660	0.0000000	0.0000000
98	300.0	1346.856	.0001127	.0008274
99	300.0	1312.160	.0001098	.0008326
100	300.0	1355.339	.0002268	.0011659
101	300.0	1327.169	0.0000000	0.0000000

STATISTICAL SUMMARY	MEAN	VARIANCE
ULLAGE VOLUME	1340.4737	1515.8083
FLOW (SCFM)	.0001361	.0000001143
HOLE SIZE (IN)	.0005103	.0000006296

TOTAL OF 17 CONTAINERS TESTED: 0 UNDER TORQUED
0 OVER TORQUED

tag, and when opened was found to contain only a partial charge. In order to maintain uniformity in the test population, this container was omitted from further testing.

Table 13 presents the results of the determination of leakage hole size for the various container/charge configurations and the overall results. As can be seen, the largest mean effective leakage hole size for any container/charge configuration does not exceed 1.5 mils while the mean effective leakage hole size for the total population of 349 containers does not exceed 1.2 mils.

Based upon the work of Somerville[4] as reported by Natrella[5], we can determine the largest value of a selected parameter for a desired confidence level such that a known percentage of the population can be said to lie below that maximum value. Applying this procedure to the effective leakage hole size and utilizing table A-31 of Reference 4 we obtain the results presented in Table 14.

This relates the leakage hole size to the confidence of finding the stated population percentage below (less than) that hole size. For example, we can state that we have a 90% confidence that 95% of all hole sizes in any test population will be less than 0.003079 inches in diameter.

Automated Load and Pack (LAP) Line Test Equipment

Requirements

Equipment destined to be utilized on automated load and pack assembly lines must be capable of detecting leakage rates that are indicative of unacceptable containers. In order to accomplish this goal, the pressure transducer used must have sufficient resolution to be able to detect the pressure decay due to leakage over and above that caused by adiabatic cooling for any container size and ullage volume.

Using the results of Table 14 in conjunction with Figures 4 and 5, we can determine the leakage factors for any population percentage, confidence level, and test pressure. Dividing the leakage factors by the container ullage volume would then result in the minimum transducer resolution needed for the selected test conditions. Table 15 presents the minimum transducer resolutions needed for a given population percentage, confidence level and test pressure, and are based upon the largest ullage volume as determined by the loaded container testing. The resolutions given in the table must be multiplied by the pressure test time in order to arrive at the true resolution needed.

The use of Table 15 can best be shown by the following example:

Problem: We wish to have a 95% confidence that 95% of all containers have leakage holes less than or equal to 0.0031 inches. We

Table 13. Summary of Loaded Container Test Results

Container	Charge	Mean Effective Leakage Hole Size
M13A2	M4A2	0.0014785
M14A2	M3	0.0010827
M18A2	M1	0.0005296
M18A2	M2	0.0007719
M19A1	M2	0.0014858
PA66	M188E1	0.0009587
PA66	M188E1M	0.0009366
PA66*	M188E1	0.0005103
Total Summary		0.0011168

Total of 351 Containers Tested:

126 Under Torqued

69 Over Torqued

17 Zero Lid Torque*

2 Omitted From Testing

* Re-Torqued then tested

Table 14. Maximum Leakage Hole Size as a Function of Confidence Level and Percentage of Population

	Population Percentage			
Confidence	0.75	0.90	0.95	0.99
0.75	0.0013309	0.001661	0.0030463	0.0087689
0.90	0.0013442	0.0018131	0.0030790	0.0122757
0.95	0.0013499	0.0018156	0.0031145	0.0122757
0.99	0.0013932	0.0022030	0.0031852	-

Table 15. Required Pressure Transducer Resolutions

Confidence	Population	Hole Size	Transducer Resolution (PSI/SEC) Fill Pressure 1 PSIG	2 PSIG	3 PSIG	4 PSIG
0.99	0.99	—	—	—	—	—
	0.95	0.0031852	0.000290	0.00421	0.00529	0.00595
	0.90	0.0022030	0.000145	0.000214	0.000268	0.000301
0.95	0.99	0.0122757	0.00442	0.00624	0.00834	0.00907
	0.95	0.0031145	0.000290	0.00421	0.00529	0.00595
	0.90	0.0018156	0.0000979	0.000143	0.000181	0.000203
0.90	0.99	0.0122757	0.00442	0.00624	0.00834	0.00907
	0.95	0.0030790	0.000290	0.00421	0.00529	0.00595
	0.90	0.0018131	0.0000979	0.000143	0.000181	0.000203

expect the container pressure test to last 5 seconds and the initial container pressure to be 3.0 psig.

Solution: From Table 14 we see that the leakage hole size was chosen consistent with the confidence level and population percentage.

Entering Table 15 with these values we see that for a test pressure of 3.0 psig, the needed transducer resolution is 0.00529 PSI/SEC. Multiplying this by the container test time of 5 seconds yields the minimum transducer resolution of 0.026 PSI. Therefore in order to conduct a leakage test under the given conditions, we must select a transducer capable of resolving pressure levels to at least 0.026 PSI.

Availability

Although it is known that several commercial firms such as Uson, Inc., and Himmelstein & Co. manufacture total systems for the determination of pressure decay in closed containers, the vast majority of leakage test equipment manufactured is of the halogen or helium "sniffer" type which does not lend itself to employment on a high speed automated LAP line.

With the advent of microprocessor control systems and their application to LAP lines, it is felt that the measurements and calculations needed for leakage rate determination can be best accomplished by utilizing these systems instead of employing a discrete test system. All accept/reject criteria would then reside in the central processor read-only memory (ROM) and the processor itself would accomplish all the necessary computations based upon a pre-stored subprogram and the data it receives from the remote pressure transducer.

The availability of equipment therefore reduces to the availability of pressure transducers with adaquate sensitivity/resolution to measure the unit time pressure decays as given by Table 15. The appendix presents a short list of manufacturers that produce pressure transducers with sufficient accuracy to be employed on LAP lines. It should be noted that this list is by no means exhaustive and that the final choice of equipment/suppliers will depend upon the specific application, the availability of the equipment, and its compatibility with the other LAP line equipment.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the efforts documented by this report, the following conclusions have been reached:

1. An adequate theory exists that relates effective leakage hole size to the observed pressure decay in the container and the container ullage volume.

2. Laboratory testing has shown a good correlation between theoretical and empirical results.

3. A maximum container test pressure has been established that is typically less than 34.5 kPa (5.0 PSIG).

4. As a result of a series of tests conducted with loaded propellant containers, a mean ullage volume has been established for each container/charge combination considered. Variations in container ullage volume, as measured, typically run between 3% and 19% of this mean value.

5. Applying the developed theory to the results of the loaded container tests has shown that the effective leakage hole size for all the containers tested is on the order of 25 micrometers (0.001 inch).

As a result of this effort and the previous work in this area[2], the leakage characteristics of propellant containers have been sufficiently determined and no further effort should be required in this area.

Due to the large number of manufacturers producing pressure transducers and the variety of sensing means employed in the transducers, no single manufacturer/transducer type can be recommended. Selection of an appropriate transducer will depend upon parameters fixed by the LAP line design, such as available test time as established by the line production rate, and the decision to employ centralized or discrete test decision logic circuits.

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2. M. Slawsky, A. Schmidlin, and M. Lutzky, "A Method For Predicting Pressure Drops in Pneumatic Components and Systems", SAE National Aeronautic Meeting, New York, NY 20-24 April 1953.

3. M. Goes, "Analysis of a Propellant Canister Leak Detection System Utilized on an 155mm and 8-inch LAP Line," DRDAR-LCN-F Letter Report to DRDAR-LCU-TP, October 1977.

4. Paul N. Somerville, Tables for Obtaining Non-Parametric Tolerance Limits, Annals of Mathematical Statistics, Vol 29, No. 2, pp 599-601, June 1958.

5. Mary Natrella, "Engineering Design Handbook, Experimental Statistics," Section 5, Tables. US Army Materiel Command, AMCP 706-114, July 1963.

APPENDIX

Selected Transducer Manufacturers

Beacon, Inc.
Bell & Howell Co. - CEC Instruments Div
Condec Corp/Consolidated
Datametrics, Inc.
Foxboro Co./ICT, Inc.
Genisco Technology Corp.
Himmelstein & Co.
Honeywell, Inc.
Lynch Corp/Cox Instruments
Robinson - Halpern Co.
Rosemount, Inc.
Schaevitz Engineering
Sensotec, Inc.
Setra Systems, Inc.
Sybron Corp/Taylor
Systron - Donner Corp.
Viatran Corp.

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